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8. Papers should average about 12,000 words in length and should be no longer than 18,000 words. As an approximation, each full page of typed text, table, or illustration is the equivalent of 300 words.

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Journal of the

AIR TRANSPORT DIVISION

Proceedings of the American Society of Civil Engineers

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A STATEMENT OF OBJECTIVE

Reginald J. Sutherland,[1] M. ASCE

A first "Jet Age Airport Conference" which was conducted by the Air Transport Division in 1957, concentrated attention on those problems that had to be solved before jet aircraft could operate from the commercial airfields of the world. Ideas exchanged at that time accelerated the work which has provided, and is providing, new and necessary facilities. To chart the gains made, and permit open appraisal of experience gained in the two years that have sped by since the first conference, this second "Jet Age" Conference was planned with special care, and conducted in such a manner as to encourage the presentation of new and thought provoking ideas. Every encouragement was given to discussion, some of which is recorded in this volume.

The object of all this is to effect the exchange of information. It is believed that the process of assembling informed representatives of the aircraft manufacturers, the airline operators, the airport operators, airport designers and planners, equipment and material manufacturers, and federal agencies does facilitate such exchange. Thus, the invitation to attend and participate was extended "to those who, directly or indirectly, are concerned with the provision and operation of facilities to serve high-speed, high-capacity aircraft now coming into general use".

This record will carry such accumulated information to many who could not accept the opportunity to attend. Attention is directed also to the May 1959, issue of CIVIL ENGINEERING which was devoted to "Jet Airport Construction" and was prepared in conjunction with this conference.

Note: Discussion open until December 1, 1959. To extend the closing date one month, a written request must be filed with the Executive Secretary, ASCE. Paper 2100 is part of the copyrighted Journal of the Air Transport Division, Proceedings of the American Society of Civil Engineers, Vol. 85, No. AT 3, July, 1959.

1. Conference Chairman, Secy., Air Transport Div., Director, Airport Flight Facilities, American Airlines, New York, N. Y.

Journal of the
AIR TRANSPORT DIVISION
Proceedings of the American Society of Civil Engineers

THE ROLE OF THE AIR TRANSPORT DIVISION

John M. Kyle, Jr.,[1] F. ASCE

It seems appropriate, in introducing the 2nd Jet Age Airport Conference, to call attention to the role being played by the Air Transport Division of ASCE. This division was authorized, upon petition of over one hundred members of the Society, with a twofold purpose: "the advancement of the science of Civil Engineering as related to the administration, economics, planning, design, construction, operation, and maintenance of civil and military airports and airways; the professional improvement of civil engineers interested in air transport and related work".

The constructive function of the division has been carried forward in conferences, sessions at conventions, the work of committees and in the encouragement of papers for publication. It should be emphasized that this division is people, rather than a remote machine of some sort that grinds out some end product. It is these men, acting from acceptance of professional obligation, who have contributed the papers with new ideas, have manned the committees and have coordinated the widespread activities of the organization.

This conference is a striking example. It is more than five general sessions, with over 30 prepared papers, set in the remarkable facilities of the Shamrock-Hilton Hotel. This conference is men with ideas, men planning, men assuming responsibilities, men participating. For the record, such men were brought together by the cooperation of the Air Transport Division, the Houston Branch of ASCE, the Airport Operators' Council and the Air Transport Association. The following accepted chairmanships:

General Chairman: Reginald J. Sutherland
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Program Chairman: John Hugh Jones
Publications Chairman: Max Weinroth
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1. Chmn., Air Transport Div., Chf. Engr., Port of New York Authority, New York, N. Y.

Hotel Arrangements: Harry E. Bovay
Registration: Ed. C. Janick
Public Relations: John A. Focht, Jr.
Women's Entertainment: Mrs. Frank H. Newnam, Jr.

Journal of the
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VTOL - STOL AIRCRAFT

Progress Report of the Committee on Air Centers of the Air Transport Division

William C. Borland,[1] M. ASCE

First, it is wise to define an air center, for the terminology is new. An air center is an area for the operation of aircraft having vertical or short landing and take-off characteristics. This landing area has been known for years as a heliport and, for the present, it is used principally by the helicopter. This will not be so in the future, as the air center will be used by steep gradient aircraft of several types. The size, shape, weight and operational requirements of these aircrafts are of major interest to city planners, architects of structures which may be utilized for air centers and certainly the engineer who will design the facility.

The mission of the Air Center Committee is to keep the civil engineering profession currently informed on present and long range operational aspects of there steep gradient aircraft and the ground facilities which will affect the establishment and/or use of landing areas.

The Air Center Committee realizes that to be of real assistance to the engineering profession, it will have to report the long range picture of future aircraft and also acquaint the aircraft manufacturer with the practical limitation of space and structures in urban areas where city air centers must be located if the flight characteristics of these aircraft are to be utilized. If the air space and landing area have not been reserved, you cannot utilize the aircraft and if you do not have the aircraft there is no need to reserve the space. The aircraft manufacturer and the city planning engineer must work together to develop a practical answer for both the flying machine and the operational area required for its use.

The members of the Air Center Committee are as follows:

Joseph Mashman, Director, Sales Planning, Bell Helicopter Corp.
Donald B. Talmage, Engineering Division, Air Transport Assoc. of America

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1. Chairman, Committee on Air Centers, Coordinator of Engineering, Port of New York Authority, New York, N. Y.

Joseph Stuart, III, Manager, Operations Research Dept., Advanced Research Division, Hiller Helicopters
Howard G. Law, LaGuardia Air Center District Office, Federal Aviation Agency
David B. Parker, Asst. Chief of Transportation, Research and Development, Department of the Army
Donald M. Thompson, Technical Director, Aviation Research and Development, Office Chief of Transportation, Department of the Army
Robert S. Angstadt, Chicago Helicopter Airways, Inc.
Herbert Howell, Chief Washington International Airport Division, Federal Aviation Agency
and William C. Borland, Coordinator of Engineering, Port of New York Authority, New York, N. Y.

These gentlemen represent the manufacturer, operator and regulatory agencies in order for the committee to appraise the problems of establishing air centers with the interest of all parties in mind.

The projects presently under study by the committee are as follows:

1. Operational characteristics of future helicopters.
2. Operational characteristics of future VTOL and STOL aircraft.
3. Aerial highway to urban air centers.
4. Design criteria for elevated landing area.

The following report does not have the unanimous approval of all members of the committee, or better, each individual member of the committee does not indorse completely the following report. The report does express an appraisal of what will happen in the next 10 to 15 years in the development of vertical and steep gradient aircraft.

The present aircraft terminology of helicopters, VTOL, STOL and convector type aircraft must be extremely confusing. It is even getting difficult today to define a helicopter because so many hybrids are being developed. The immediate future will see many more. To simplify the terminology of this paper, all aircraft that would utilize an air center as urban aircraft will be referred to as the U-X-75.

Reviewing the development of transport aircraft for the past 50 years reveals some interesting information. Certain constants that have remained for years in the design of transport aircraft will be utilized to develop the theoretical U-X-75. The first and only real constant that industry has had is the physical dimensions of a human being. To get a start on developing the future urban aircraft some assumptions are necessary. The first of these will be that it will carry 60 people with limited room for baggage and mail. The area required to seat 60 people in a conveyance is roughly 500 square feet. Doubling this area or 1,000 square feet will provide room for not only engines but also a cockpit, baggage, instruments and airstreaming the box but does not cover the area for external appedages required for lift or control such as wings. The shape of the aircraft could be a circle, square, a rectangle of varying dimensions or a triangle of many configurations. The fuselage of transport aircraft, have and still do, resemble a thick cigar. We will make use of this second constant to place some dimensions on our 1,000 square foot aircraft. As the thin rectangle makes calculations easy let us use the configuration. For the present the height of the fuselage will be the same for all aircraft. Using present day aircraft as a yardstick the width of the fuselage

would be about ten feet and therefore using 1,000 square feet as the area of the fuselage the length would be 100 feet. It appears reasonable that rotor blades, control surfaces, wings and other appendages would not exceed the greatest dimension of the machine.

The area that one aircraft would occupy would therefore be a circle having a diameter of 100 feet. In other words the future urban aircraft would fit into a circle 100 feet in diameter regardless of shape. To provide proper clearance for maneuvering, servicing and unloading, an additional 20 feet should be provided on all sides of the aircraft. The diameter of the circle thus becomes 140 feet. For the want of a better term, this will be termed the operating perimeter of the future urban aircraft. Thus the cigar shaped machine with conventional rotors can be operated in the same perimeter as the tilt-wing convertor plane and the ducted fan aircraft with its internally-mounted power plants. The shape could be a circle, square, rectangle or triangle. As to the physical appearance of the future urban aircraft all that can be said is that it will operate within a perimeter of a circle having a diameter of 140 feet. To be more specific, it is necessary to determine fuselage configuration, power plants and the method of transmitting this power to lift. In doing so it is necessary to select the flying machine that will be in use in 1975. With the number of concepts of urban aircraft being developed today the selection of any one design would be extremely hazardous. Next let us determine if there is any logical method of predicting the weight and landing gear configuration of the future U-X-75. Again let us go back to the standard citizen. The airlines have used for years an average weight of 200 pounds for a domestic passenger and his baggage. Using this criteria the passenger payload of our 60 passenger aircraft would be 12,000 pounds. The ratio of payload to maximum gross weight for recent transport aircraft is in the neighborhood 1 to 5. While we can all expect this factor to improve it is remarkable how close the ratio of payload to gross weight has remained to the above figure from the days of the old DC3 to the present jet aircraft. Using the 1 to 5 ratio the maximum gross weight for the future urban aircraft would be 60,000. If the ratio improves the operator will throw on some mail so the figure of 60,000 pound maximum gross weight for our future aircraft appears to be reasonable.

For this information to be of use to the designer the distribution of this weight on the landing area must be determined. The unit loading on the landing area is related to the tire pressure of the aircraft. The following criteria has been discussed by members of the Air Center Committee with the Helicopter Committee of the AIA and the Airport Division of the FAA regarding the impact loading of the landing area. The criteria is as follows:

> "The landing area should be designed to take a maximum impact load of 1-1/2 times the static loading of one of the main gear distributed over a foot print area of such magnitude that the unit loading of the land area will not exceed 100 psi."

Thus the tire or tires must be of such size that the impact loading will not exceed 100 pounds per square inch.

The spacing of the landing gear is also of interest to the designer. It appears that the lateral spacing will be in the neighborhood of 20 feet and that the longitudinal spacing will depend on the shape of the fuselage. However, the longitudinal spacing of the gear should exceed the lateral spacing unless the aircraft sets on its tail and the passengers climb a ladder to get aboard.

Gear configuration will vary with the shape of the machine, the type of power plants and many other factors, so the above criteria is the best that can be developed today.

Some of the information required to design an air center is being developed that will in all probability remain valid for the aircraft of 1975 even though we cannot describe the machine.

Next, examine the probable landing and take-off requirements of the aircraft and its maneuvering ability on the ground. The operating perimeter of a circle having a diameter of 140 feet has been established so the landing and take-off area will be a function of some length by a width of 140 feet. It should be borne in mind that the aircraft must obtain sufficient height over the landing area to clear surrounded obstructions and to fly a precise flight-pattern or to return to the landing area should mechanical difficulty demand. Present indications are that the take-off maneuver will not be a vertical climb for several hundred feet and then coverting to horizontal flight but rather a steep accent which will combine forward exceleration and vertical climb. A ratio of four feet horizontal to 1 foot vertical is the suggested flight pattern for take-off. Landing should safely be made at about twice the rate of climb or a descent of two feet horizontal to one foot vertical. While there is little doubt that by 1970-75 the aircraft will achieve one engine out performance there is wide divergence of opinion as to what the flying capabilities of the aircraft will be. There is no doubt that for passenger service the operation must be safe. It is suggested that the aircraft should obtain an altitude of 100 feet before it loses the ability to return to the landing area. Assuming that this maneuver will require flying in a straight line the landing area must approximate 600 feet long using the 4 to 1 ratio for take-off and the 1 to 2 ratio for landing. The take-off area thus becomes an area of 140 feet wide and 600 feet long. As the aircraft will occupy a certain area, before take-off and after landing, the 600 foot landing strip should be lengthened an additional 100 feet for a total length of 700 feet. Routine landing can easily be accomplished in this area. The aircraft will be capable of operating with cross-wind components of such magnitude that for practical purpose a landing area oriented in the direction of the prevailing winds will suffice. Little can be said of the ground maneuverability of the aircraft other than it will be self-powered and be capable of taxing to and from gate positions of the size of the operating perimeter. In all probability power will be transmitted directly to the wheels and thus eliminate the rotar or propeller blast which would be troublesome for congested loading areas. The number of gate positions, size of parking area, passenger terminal facilities and aircraft servicing facilities will depend on location of the Air Center and the traffic that it will handle. The only dimension that can be used with any certainty is the operating perimeter of 140 feet. At first this width would appear excessive for parking areas for fuselage configurations other than the flying cigar. Keeping in mind the design criteria of a fuselage area of 1000 square feet and that external appendages such as rotors, wings etc., would not exceed the longest dimension of the aircraft the width of 140 feet can be utilized efficiently by either nesting the aircraft or double parking the shorter versions. Some trial calculations show that a variety of configurations of numerous dimensions can make good use of the area. The long thin aircraft will probably have folding rotors or wings which will allow several aircraft to be parked on a frontage of 140 feet.

For capabilities of the U-X-75 in the air, it has been established that it will climb better than one foot vertical for every four feet horizontal on take-off.

In engineering terminology it will climb a 25% grade and in aviation lingo it will operate in a 4 to 1 approach zone.

The range will be in the neighborhood of 300 miles. This will, of course, vary with the type of aircraft and the location of the air center. In densely populated areas such as we have in the east the range might be less and conversely in the mid-west and west the range might be considerably more. It really depends on how much fuel you must haul around to get to your traffic generating centers.

The aircraft will probably be powered with turbine engines which at first will be noisy. This noise combined with the rotor or propeller precussions will be of concern to those responsible for the location of the air centers. Improvements will be made to reduce this noise and by 1975 it should be no more troublesome than our present truck traffic. The speed of the machine will vary with the type of aircraft. It will probably range from 150 miles per hour to over 300 miles per hour. Using the above information the traffic engineers will be able to give the designers of the air center some data on terminal size, parking area requirements and all the other information that he will need to complete his design.

Next, what will be the problem of getting the urban aircraft to and from the air center? Numerous systems of precise navigation are under study today. These systems while they vary in concept are all striving to develop a technique for instrument flying which will equal the pilot of the aircrafts ability to fly under visual flight conditions. The results are encouraging enough to predict that by 1970-75 the pilot of the U-X-75 will be able to fly a complicated flight pattern under zero-zero conditions with the same accuracy as he could under visual flight conditions.

With the air traffic density that will exist in 1975, the approach to the urban air center must in reality be an aerial highway system with traffic following a rigid flight pattern. The aerial highway will probably have clover leaf intersections and many of the features of a modern high speed turnpike. The one great difference is that it will have three dimensions as the vertical position of the vehicle will no longer be fixed by a strip of pavement. It appears that the enroute highway will be a box roughly 500 feet square with a single aircraft occupying a block 2,000 feet long. Sure traffic intervals will be much greater than on our present highways but remember that a series of black boxes will replace the strip of pavement. Ten or more lane highway systems are possible. Interchanges, overpasses, underpasses, high and low speed traffic lanes as well as emergency lanes, landing areas and many features not yet dreamed of are in the offering. Think of the freedom of design that the highway engineer will have when terrain features are no longer a consideration and grades are 25% instead of 5%. All that is required is a system of black boxes to define the aerial traffic lanes and reliable instrumentation that will allow the pilot to fly with the same ability as if he could see 20 miles in all directions.

It is as hard to visualize a railroad signal system controlling all the movements on this aerial highway system as it would be to control automotive traffic with the same system. The pilot will have to drive his urban aircraft much the same as the bus driver of today.

Summarizing:

1. The box carrying 60 people will have an area of approximately 1,000 square feet. Shape can be almost anything.

2. The longest dimensions will be in the neighborhood of 100 ft.
3. The operating perimeter of the aircraft will be a circle having a diameter of approximately 140 feet.
4. The gross weight will be approximately 60,000 pounds.
5. The unit load on the landing area will be 100 psi.
6. The landing gear will be spaced so that the minimum distance between gear will be about 20 feet.
7. The dimensions of the take-off area will be 140' x 700'.
8. Single directional take-off area oriented to the prevailing winds will suffice.
9. The vehicle will be self-powered and capable of taxiing to and from a gate position equal to the operating perimeter of the aircraft.
10. Parking areas should have a depth of 140 feet.

Respectfully submitted,

Robert S. Angstadt
Herbert Howell
Howard G. Law
Joseph Mashman
David B. Parker
Joseph Stuart, III
Donald B. Talmage
Donald M. Thompson
William C. Borland, Chairman

Committee on Air Centers of the Air Transport Division

Journal of the
AIR TRANSPORT DIVISION
Proceedings of the American Society of Civil Engineers

AIRCRAFT OF THE FUTURE AND PORTS FOR MODERN FLIGHT VEHICLES

Charles S. Draper[1]*

During little more than half a century, the aeronautical progenies of the Wright brothers flyer have expanded until they now provide service for all regions of the earth's atmosphere and are well started toward operations in the space that lies beyond. Speeds have increased from forty miles per hour in 1903 until routine passenger flights are now made at over six hundred miles per hour, and we can reasonably expect the next generation of aircraft to operate at over two thousand miles per hour. Useful loads have changed from a single man, the pilot, until now passenger lists with between one hundred and two hundred names are not unusual and freight cargoes may be several times ten tons. The end of progress is not yet in sight. We can look forward to higher performance and better transportation efficiency as advances are made in the science and engineering of flight vehicles.

Astronautics encompasses the art and science associated with flight vehicles designed to operate outside the atmosphere and is now in its infancy with some ballistic missiles started in production, a few satellites in orbit, and some missed lunar shots on the record. However, the next few years will bring very great developments of astronautical vehicles and all the other elements needed to realize transportation systems based on these vehicles.

It is the purpose of this paper to consider the state of the flight vehicle art in broad terms with some attention to possible directions for future developments and to suggest some features that may be used in the flight ports of future transportation systems. The key difficulties that must be overcome by the design of ground facilities are considered, and the general nature of a possible flight port of the future is described. The paper is presented in the hope that worthwhile discussions will be stimulated by the admittedly controversial concepts that are illustrated.

Note: Discussion open until December 1, 1959. To extend the closing date one month, a written request must be filed with the Executive Secretary, ASCE. Paper 2103 is part of the copyrighted Journal of the Air Transport Division, Proceedings of the American Society of Civil Engineers, Vol. 85, No. AT 3, July, 1959.

1. Prof. and Head, Dept. of Aeronautics and Astronautics, Director, Instrumentation Lab., Massachusetts Inst. of Technology, Cambridge, Mass.

*Slides were used to illustrate Dr. Draper's presentation.

Flight Vehicles of Today and Tomorrow

Flight ports must be designed to accommodate the requirements of the particular craft that will use them. Because there are many different types of flight vehicles, ground facilities need to have such a wide variety of features that it is not only difficult but almost impossible to incorporate all of them in ports of reasonable size and cost. In order to understand what these features are and the factors that cause them to exist, it is useful to examine Fig. 1. This figure displays the spectrum of present and future flight vehicles. The typical vehicles are numbered from 1 through 15 starting with the helicopter and ending with an interplanetary craft. Each vehicle is placed above the earth in the region of its normal operating altitude in miles. The scale is made logarithmic in order to accommodate the very great range of distances involved. As pertinent facts of performance for each vehicle type, the maximum speed in Mach number* units and the ratio of thrust to weight at take-off are listed in a table on the right-hand side of the figure.

*Mach number is the ratio between vehicle speed and the speed of sound in the undisturbed gas within which the vehicle moves.

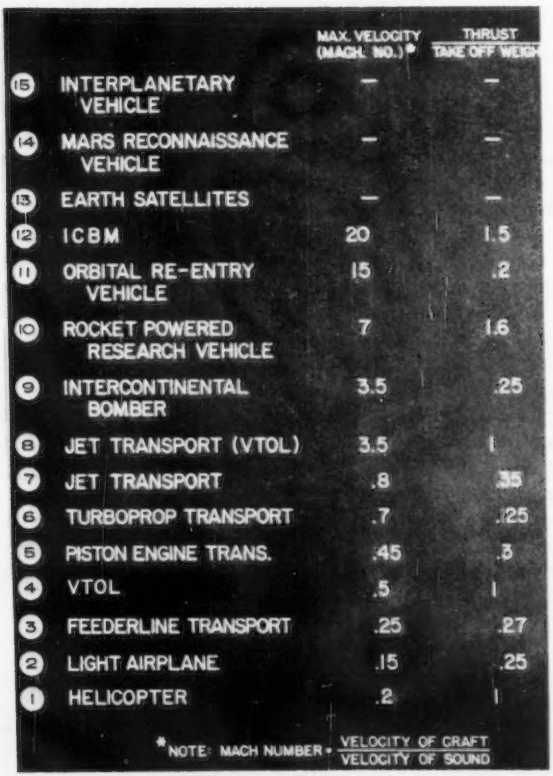
MAX. VELOCITY (MACH. NO.)*
THRUST
TAKE OFF WEIGH
15 INTERPLANETARY VEHICLE — —
14 MARS RECONNAISSANCE VEHICLE — —
13 EARTH SATELLITES — —
12 ICBM 20 1.5
11 ORBITAL RE-ENTRY VEHICLE 15 .2
10 ROCKET POWERED RESEARCH VEHICLE 7 1.6
9 INTERCONTINENTAL BOMBER 3.5 .25
8 JET TRANSPORT (VTOL) 3.5 1
7 JET TRANSPORT .8 .35
6 TURBOPROP TRANSPORT .7 .25
5 PISTON ENGINE TRANS. .45 .3
4 VTOL .5 1
3 FEEDERLINE TRANSPORT .25 .27
2 LIGHT AIRPLANE .15 .25
1 HELICOPTER .2 1
*NOTE: MACH NUMBER = VELOCITY OF CRAFT / VELOCITY OF SOUND

Fig. 1. Flight Vehicles Aeronautic - Astronautic

Aircraft types that may reasonably be expected to operate from airports with short runways are numbered 1, 2, 3, and 4 in the table of Fig. 1. Helicopters must have a take-off thrust-to-weight ratio of unity in order to rise vertically and they have maximum speeds equal to about twenty per cent of sound velocity. Light airplanes generally have similar maximum speeds with thrust-to-weight ratios of about twenty-five per cent. This discrepancy between thrust and weight has been generally characteristic of aircraft and is the basic reason that an airfoil-shaped wing is required to generate take-off lift by accelerating a large mass of air downward. Feeder-line transports for medium-length runways are typified by the well-known DC-3's, which fly at about Mach 0.25 and have a thrust-to-weight ratio at take-off of about 0.25. VTOL (Vertical Take-off and Landing) aircraft are currently being developed which have thrust-to-weight ratios of unity so that they can make vertical take-off, and they may fly at maximum Mach numbers of about 0.5. These include tilt wing, deflected thrust, tilt duct, and convertiplane or compound airplane type configurations. Once aircraft designed in this way are in the air, they convert to conventional-type flight and have the general characteristics of fixed-wing airplanes. Vehicles of this kind are not in production as yet, but flight trials with a number of prototypes and test-bed models have proved that aircraft using these principles are operationally feasible. The January, 1959, issue of the JOURNAL OF THE AMERICAN HELICOPTER SOCIETY is largely devoted to descriptions of various VTOL designs and reviews of currently available test data.

Aircraft types requiring airports with long runways (seven thousand to ten thousand feet in minimum length) are given numbers 5 through 9 in the table of Fig. 1. Conventional piston-engine transports, such as the Lockheed Constellation, the Douglas DC-6, and the Douglas DC-7, fly at maximum Mach numbers of about 0.45 and have variable-shape wings to realize take-off thrust-to-weight ratios of about 0.25 at take-off and 0.1 for cruising. The take-off ratio is not accidental, but is based on the fact that it is feasible to design wing-fuselage combinations able to lift weights approximately four times the available thrust. Turboprop transports now in service fly at about seventy per cent of sound velocity and have thrusts for cruising equal to about one-eighth of take-off weights, and at actual take-off this ratio is about 0.35. Jet transports like the Boeing 707's which are now used in commercial operations fly at about eighty per cent of sound velocity and have thrust-to-take-off weight ratios of about 0.25 at take-off. During cruise this ratio is reduced to about 0.1.

Beyond the existing aircraft types that have been mentioned, the next advanced development appears to be Mach 3.5 jet transports and intercontinental bombers, which are associated with numbers 8 and 9 of Fig. 1. The bomber, which has a great premium on load and range, is shown with a take-off thrust-to-weight ratio of 0.25. On the other hand, the power plant required for Mach 3.5 speed may for a small increase in weight be adapted to provide a thrust equal to the take-off weight of a fully loaded commercial transport. This introduces the very attractive possibility of vertical take-off and landing of jet transport aircraft. This subject is discussed by James A. O'Malley, Jr., in the reference already cited.

Number 10 on the table of Fig. 1 is a rocket-powered research vehicle with a maximum Mach number of 7 and a take-off thrust-to-weight ratio of 1.6. The only vehicle of this class that exists today is the X-15, a hybrid device designed to provide manned flight both within the atmosphere as an

aeronautical craft and in the astronautical regions outside the atmosphere. It is not expected that the X-15 design will be usable for practical operations, but the information gained from tests of the experimental models will surely be helpful in designing later vehicles. Number 11 of Fig. 1 illustrates an orbital re-entry vehicle which is placed in a satellite orbit by booster rockets. This vehicle may move at speeds near Mach 15 as it re-enters the atmosphere. The thrust-to-weight ratio of the vehicle itself is relatively low at about 0.2.

Intercontinental ballistic missiles have take-off thrust-to-weight ratios in the region of 1.5 and achieve maximum speeds of about Mach 15 based on conditions in the upper atmosphere.

Craft such as earth satellites and interplanetary vehicles operate outside the atmosphere, so that Mach number is a meaningless concept. Take-offs for vehicles of this kind are made with the aid of booster rockets, so that the take-off thrust-to-weight ratio for the vehicle itself also has no significance.

Flight Ports for the Future

For the purposes of this paper, small and medium-size airports can be considered as well-established, are reasonably satisfactory, and will probably not be greatly changed in the future. The air terminals that now serve the principal domestic and foreign airlines using propeller-driven craft surely need to be improved in many ways, but they are now providing fairly well for a large and thriving transportation industry and no more than a few of them are likely to be greatly changed during the next few years. The new subsonic, pure-jet transports place severe requirements on conventional airports because of the great runway lengths that they require for take-offs and landings. Noise, short allowable holding times on the ground and in the air because of the high rates of fuel consumption, and difficulties with speed differentials over other aircraft introduce problems that must be worked out by development of the means now at hand.

It is in the next generation of air transport systems, based on Mach number 3.5 jet aircraft with take-off thrust-to-weight ratios of unity, that modern features can be designed into flight ports.

Supersonic Jet, VTOL Aircraft and Their Problems of Operation on the Ground and in the Air

Supersonic speeds from jet transport aircraft are not achieved without paying considerable costs of various kinds in design and in operation. The difficulties in vehicle design must be overcome by the engineers whose aims are to reduce concepts and ideas to actual equipment. Problems of this sort are not the primary concern of this paper. The aircraft characteristics of direct interest here are those that are troublesome in practice, those that can cause annoyance and discomfort to passengers, and those that may disturb persons living or working near airports. One of the purposes of this paper is to discuss means for eliminating or alleviating the troubles associated with the use of VTOL jets in transportation systems.

Problems in applications of jet aircraft are largely associated with two basic characteristics of the power plants:

1. Jet engines are very strong noise sources when they are operating at high thrust and produce severe air disturbances with their exhaust jets.
2. Jet engines consume fuel very rapidly whether they are running efficiently at high flight speeds, operating inefficiently at lower thrust in slow-speed flight, or stationary on the ground.

The noise problem may be attacked by exhaust silencers, which reduce noise somewhat, but always entail an appreciable cost in thrust reduction. To protect neighbors from jet-engine noise during landings, take-offs, climb-outs, and taxiing procedures, various means for attenuation, deflection, and absorption are possible. Minimizing the periods during which jets operate is also very effective in reducing the number of complaints from neighbors caused by the noise nuisance.

When the regular engines are used for taxiing airplanes, partitions of some kind to protect passengers and airport personnel in the terminal and considerable space between the running power plants and other inhabited craft are means for tolerating propulsion blast effects.

The high fuel consumption rates of jet engines in flight and on the ground mean that the total flight time available from the amount of fuel that may be carried is sharply restricted. To conserve fuel before flight, it is very important to take off as soon as possible after engines are started. To complete flights safely, delays due to holding in traffic patterns from any cause must be minimized. In particular, it is necessary to eliminate the effects of weather on flight times. Schedules must be maintained as well in the worst weather as in the best weather. With the guidance techniques and equipment now available from military missile developments, such as the NIKE, BOMARC, MATADOR, REGULUS, and HAWK, it is certain that aircraft could be safely and accurately taken off, navigated between airports, and landed without interference by weather. The guidance phase of flight operations is now being rapidly developed and can be expected to reach a satisfactory stage of performance within the next few years. This paper is not particularly concerned with guidance beyond the general assumption that means are available for controlling and guiding aircraft after they become air-borne on take-off and until the moment of touch-down on landing.

General Functions of Flight Ports

Flight ports have the functions of accepting passengers and freight from all means of transportation that may be available, making effective transfers to operational aircraft, and providing for safe and expeditious take-offs and landings. For example, a flight port for Mach number 3.5 VTOL jet aircraft may reasonably be expected to have provisions for passengers arriving by air from major airlines, helicopter taxis, and VTOL craft, and from buses, private cars, and rapid-transit systems. These passengers and their effects should be handled rapidly and with the smallest possible inconvenience and discomfort while they wait for take-off. Boarding and disembarking operations should be done quickly so that passengers do not have to wait in their aircraft for extended periods either before taking off or after landing.

Finally, flight ports should be designed to be as small as possible and to be good neighbors from the standpoint of noise for those who live and work near them. Access roads should be distributed to accept traffic from various directions with minimum congestion and adapted for smooth flow of both

pleasure cars and freight-truck traffic even at peak-load hours. Service facilities and test locations should be well separated from passenger accommodations and designed to have sufficient capacity to care expeditiously for the aircraft required to maintain normal operations at the port.

Motorized Driver for Handling of Aircraft on the Ground

Fuel waste in taxiing and holding operations may be entirely eliminated by means of an auxiliary driving unit built for temporary attachment to aircraft on the ground. A unit of this kind would conserve fuel by making it unnecessary to start the main engines until the aircraft has reached the take-off point, is ready to start, and has clearance for immediate departure. When these circumstances exist, the driver unit, which effectively serves the same functions as a tug for large ships or a switch engine for railroad cars and also provides service power, air conditioning, et cetera, is disconnected and driven to another aircraft which is in need of taxiing force and general service power.

As by-products of applying an auxiliary driving unit for ground operations, noise from main engines is completely eliminated until just before lift-off and difficulties with exhaust blasts no longer exist in congested areas of the flight port.

Noise Control with VTOL Jet Transports

When engines are started and the high thrust settings required for lift-off are made, high noise levels will unavoidably exist in the vicinity of the lift-off site until the aircraft has reached a considerable altitude. The inherent soundproofing of the aircraft will protect passengers and crew inside the fuselage, but neighbors may very well have justified complaints. This difficulty can be reduced by conducting the lift-off operation from an area that is enclosed by a sound-control shell. This shell might have a roughly parabolic shape formed by an open latticework wall and a volume behind the wall enclosed by sound-absorbing material. By directing the open end of the parabolic shape upward, sound energy from the jet blasts is partly directed toward the open sky and partly absorbed. The fraction of the total sound energy that is sent toward the outer atmosphere will generally not return to be heard on the ground. This process will be less effective when reflecting layers, such as clouds, exist in the atmosphere, but troublesome noise should be greatly reduced during the initial stages of lift-off.

When VTOL jet planes are in the air but not yet high enough for atmospheric attenuation to control noise, areas of trees planted in the vicinity of lift-off areas should deaden sound effects to a considerable extent. Only the results of theoretical and experimental studies can supply exact information on noise control, but it is reasonable to assume that effective means for this purpose are feasible. Because of the limited areas involved during lift-offs, VTOL operations are more adaptable to noise-reduction measures than the long runway areas required by conventional aircraft.

Flight Terminal Features for Comfort and Convenience of Passengers

Flight terminals should be designed so that passengers may arrive by any means of transportation and have their tickets and baggage expeditiously and

conveniently processed. With baggage cared for, pleasant lounges of ample size should be provided for the use of passengers and their friends until boarding time. The operation of boarding should be rapid and direct and not require passengers to go through or stand in uncomfortable areas. Walking and climbing stairs or ramps should be reduced to a minimum, and enough access doors should be provided so that loading for an aircraft can be completed in less than ten minutes.

The desirable conditions outlined above should exist for both loading and unloading operations. For unloading, baggage should be available by the time passengers have reached the exit area, and convenient means for reaching personal cars, VTOL taxis, automobile taxis, buses, VTOL buses, and rapid-transit facilities should be available. Except when distances are very short, moving sidewalks should be provided, and escalators should be used in all situations where a change in floor level is involved.

Compactness, roominess, comfort, convenience, and pleasant surroundings for passengers and their companions are primary requirements for flight ports. These conditions can be fulfilled only by designing terminal buildings with various levels and furnishing the passengers with attractive outside rooms which have large windows and facilities for food and refreshments.

Loading and Unloading with Aircraft Brought Directly to the Passenger Lounge Area

A suggested loading and unloading arrangement would permit passengers to remain in a comfortable loung area until their aircraft is literally brought to the doorstep silently and smoothly by the pilot driving his aircraft with a ground power unit. Once the aircraft is in position, comfortably wide escalator loading ramps are raised to match the aircraft doors, and passengers enter directly from the lounge. The aircraft is brought to the loading dock only after the completion of fueling and all other service operations and with the crew aboard and ready to start. While passengers load from the second-floor level, baggage is placed aboard in already packed units fitted with means for attachment to rails fixed in the aircraft. Using special elevator-type trucks and automatic locking devices, it should be possible to complete loading in less than ten minutes. Even with the large aircraft involved, passengers should be aboard and settled in their seats by the time baggage loading is finished. With passengers aboard and loading completed, the pilot seals his aircraft and drives at the maximum safe speed to his assigned lift-off shell.

The ground level contains baggage checking, baggage and freight handling, ticket control, and other functions required to care for passenger needs. Aircraft operations, pilot briefing, weather information, and other functions of this kind would be housed in a separate service building, not in the passenger terminal.

The passenger level includes all the facilities needed for the comfort, convenience, and amusement of customers while waiting for flights, planning trips, expecting friends, eating, et cetera. The pilot drives up in his vehicle only after all flight preparations for the aircraft have been made in service areas, so that passengers are never required to stand in line or wait while final preparations of any kind are made.

The VTOL service level is on the roof of the passenger level. Helicopters with a capacity for two or three passengers supply taxi service; larger

helicopters and other VTOL aircraft are available for longer scheduled trips; and private VTOL craft may be parked while waiting for their passengers to arrive.

The disembarkation section of the passenger terminal has ports into which the pilot may drive his craft after his main engines are shut off and a ground power unit has been attached. The unloading of passengers and distribution of baggage should not take more than ten minutes. Freight is not unloaded at the passenger terminal, but is handled at the freight terminal and sent directly to various other means of transportation.

Over-All Plan of Flight Port

A single airline might have one or more passenger-service sections, depending upon the amount of traffic to be handled. The sections would differ in detail in order to accommodate the plans and preferences of individual airlines, but it would be desirable to preserve the concept of complete devotion to passengers in each section. The various sections would be interconnected by passageways and moving walkways as required, and escalators at convenient intervals would be provided between the levels.

General Plan of Flight Port for VTOL Jet Transports

A suggested arrangement of a VTOL jet flight port would provide five landing shells to handle a maximum of sixty aircraft an hour on the basis of a five-minute cycle per landing. A similar number of lift-off shells makes the same rate of departures possible. The passenger terminal building has ten loading docks and ten unloading docks so that the full capacity of the port may be realized. The time spent at the passenger terminal is twice the time taken at the landing and lift-off shells for each operation. Service areas are provided to accommodate about one and one half times the number of dock spaces for aircraft. Space at the flight port is conserved by bringing fuel directly in by pipeline and by depending on commercial steam and electricity for heat and power. A stand-by power plant is placed at the field to care for emergency situations.

The control tower is located on the end of the passenger terminal that is nearest the landing and lift-off shells. All offices and facilities not specifically connected with passenger contacts are in the service building.

Arriving aircraft are set down in designated shells in the landing area, ground power units are fitted, the pilot drives to his assigned dock, the passengers disembark, baggage is unloaded, the pilot drives to the freight area, and the aircraft is unloaded while refueling and other service operations are completed. When the aircraft is ready for a new flight, freight is loaded; the crew comes aboard, probably by ramp from a second-floor level; the pilot drives to his designated loading dock; passengers come aboard; baggage is placed on the aircraft; and the pilot backs away and drives to his proper shell, where he lifts off after the ground power unit is disconnected and sent to pick up another plane.

Two four-lane, divided roads pass through a sunken level under the central part of the passenger terminal. These two roads are connected outside the flight port area, but in general give uncongested access to the flight port from different directions. Escalators or moving ramps from a wide section between

the two four-lane roads carry passengers from private automobiles, taxis, and buses up to the service level, where baggage is checked, tickets are purchased, and trips are arranged. From the service level passengers and their friends go up escalators to the passenger level. Those arriving on flights reverse the course just described for departures.

For the convenience of those who wish to drive to the flight port in private cars, ample parking lots are provided. Entrances to moving walks below ground level are placed at intervals so that maximum walking distances from parked cars are reasonably short. The moving walks deliver passengers directly to the ticketing and baggage-checking areas.

Freight and supplies are delivered via four-lane, divided roadways to loading platforms placed under ground level in the service buildings. By making the service access roads come into the flight port at right angles to the automobile roadway tunnels, truck and pleasure-car traffic is protected from entanglements in the vicinity of the port.

Rapid-transit lines run parallel to the service roadway tunnel on a level below the automobile road. Station facilities are centrally located under the passenger terminal with escalators for access to the service level and the passenger level.

SUMMARY

Flight ports following the pattern presented in the figures may never be built, but it is hoped that some of the concepts suggested may serve to direct attention toward the deficiencies in present air terminals. With the volume of air traffic already tremendous and surely due for great increases with advanced equipment, thought must be given not to temporizing solutions for troubles as they occur but to a thorough revision of the whole pattern made up of flight vehicles, guidance, control, ground facilities, and connecting transportation. The air transport system as it now operates is the result of a continuous growth from the days of "cow pasture airports" and barnstorming pilots. What we need is a fresh look at a mature means for moving men and materials that is tremendously more powerful than anything that has existed before our time. We will work out solutions to all the problems involved, but only as a result of imaginative thinking and hard work. The events ahead will be very stimulating and most interesting. It is an inspiring experience to have a part, however small, in shaping the future.

ACKNOWLEDGMENTS

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AIRCRAFT FUELING SYSTEMS FOR JETS

James P. O'Donnell,[1] F. ASCE

Along with the many advantages offered by jet transportation are various problems caused by special treatment that the new aircraft require. Many airport storage and handling practices used in refueling piston-powered aircraft will be unsatisfactory for turbine-powered jet planes.

In this brief review only the highlights of design principles and considerations involved in airport fueling system for jets have been mentioned. Development of equipment and application techniques in many other items such as the following is still in progress:

Improved micronic filtering and dewatering equipment which will assure the actual fuel purity required in aircraft fuel systems and engines in all flight environments, particularly at low temperatures. The establishment of the performance specifications for such equipment to assure this required fuel purity is a problem not yet resolved.

Continuous monitoring equipment to check fuel purity throughout the handling cycle of the airport system from fuel receipt to plane loading, especially at the latter point.

Inert gas pressuring techniques for fuel transfer from storage, thereby eliminating vapor hazards, product loss and air-borne contamination at storage.

Improved design details, such as swing-joint or equivalent high-strength type connectors on hydrant carts, minimum vapor type seals for floating roof storage, submerged inlets and charge relaxation devices to reduce static electricity hazards, and floating suctions to reduce contaminant withdrawal from storage tanks.

Digital computers applied to system control, inventory, metering and billing; and analog techniques applied to quality control.

Mobile or fixed equipment to remove objectionable fuel vapors released from plane vents during fueling operations.

Suitable non-ferrous piping and equipment to reduce fuel contamination due to corrosion.

The selection of specific equipment and design techniques for individual airport systems will depend on features of safety, efficiency and economy

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thereby introduced. In evaluating such economies, it is important to consider the overall savings in aircraft operations which result when refueling is performed only from airport systems maintaining strict purity control of all fuel loaded into aircraft tanks.

The presentation of data supporting this summary was published in Civil Engineering for May, 1959, on page 53.

Journal of the
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THE PATTERN OF FUTURE AIR TRAVEL DEMANDS

J. W. Pocock[1]

In the air transportation system the most important physical elements are the aircraft, the airspace, and the airports. These can not be effectively studied separately.

Air carriers is a familiar term. General aviation may not be as familiar. It is given a group theory definition of being all civil aviation activities other than air carrier. This definition is sometimes altered in practice, but it brings great comfort to my logician friends. General aviation, then, includes business flying, instructional flying, agricultural flying, pleasure flying, etc.

In the past ten years scheduled air transportation activities have just about tripled. For next year (1960), the Federal Aviation Agency looks to the airline industry's generating 35 billion passenger miles, 5 billion more than estimates for this year. By 1970, the FAA estimates there will be 60 billion passenger miles, double the present level.

If the growth of the air carrier industry can be considered as spectacular, then that of the general aviation activity can be considered explosive. Today, general aviation is flying about 70,000 planes, just about forty times the number in our air carrier fleet. These 70,000 aircraft are flying 12 million hours a year, more than triple those flown by air carriers. Even on the basis of passenger miles, general aviation has claim to a higher figure, and it is increasing.

The most vivid color in the general aviation design is business flying. It alone exceeded airline hours by almost 2 million. It has long been expected, and is now true, that business flying has become a stable element in our industrial and business economy.

The sense of these figures is clear. General aviation is a major user of our air transportation system and of our airport network. This position is based on a solid foundation of business flying activity and on anticipated business growth. The utility airplane is no longer a luxury. For many corporations it is as vital as the company car.

As to the future, estimates put the general aviation fleet at about 105,000 units by 1975 and the total flying hours somewhat over 20 million. Remember,

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now, that the considered opinion of experts looking at airline expansion is that the carrier fleet will remain relatively static at around 1,800 planes. Increased speeds and loads will be substituting for additional planes. This means, then, that general aviation will be speeding ahead in number of planes at least as far in the future as we can project.

The main characteristic of general aviation requirements can be briefly stated.

First, the airport facilities requirements of these planes are, as we know, far less demanding than those required by airline aircraft. General aviation planes are not normally high performance aircraft. They therefore can be accommodated by relatively short runways, taxiways, and, indeed, in many instances by well-prepared sod strips.

Second, and extremely important, the number and location of our secondary airports must be such that they can efficiently service the general aviation community. This means a number of secondary airports distributed around metropolitan areas, less densely in suburban and rural areas, but sufficiently dense to care for the public and their general aviation needs.

Third, we have need for general aviation to get into the super-airport to tie in with airline flights.

We have something over 7,000 airports in this country, and this includes everything from large terminals down to identified flight strips. Yet we don't have enough of them nor are they in the right places to satisfy our needs. In addition, in most instances, those that we do have are not sufficiently modern to meet the standards of present-day aviation. These points were explicitly brought out in a report submitted by Mr. Edward Curtis to President Eisenhower. (This report, incidentally, led to the formation of FAA.) In an introductory statement, Mr. Curtis said, "Of all elements in our national system of aviation facilities, airports have been most neglected."

On this last point, the FAA has now put a figure of $1.3 billion as the money needed over the next four years to update our airport complex. Previously, about a year ago, the National Association of State Aviation Officials also inventoried the general requirements for airport modernization and development. Their figure for the money needed for the next four years was something over $1 billion, which admittedly was conservative. Thus we have agreement as to the magnitude of the updating problem and as to the cost of its solution.

The rate at which our aircraft industry is producing and selling aircraft to business and private owners is sufficient to require one new average airport each day in the United States. This is a fantastic figure. Every day we are needing another airport—think of it—365 airports a year; and on Leap Year, 366.

There are in the United States perhaps 6,500 airports which we can say serve primarily general aviation. Many of these are privately owned, over 60%. With these last we have a problem which you can readily appreciate. The entrepreneur has taxes to pay which rise as the rural community turns suburban. Then as the community develops, his new neighbors complain about noise; new industries rise; smoke stacks or power lines or TV transmitting towers appear; and real estate developers begin making love to the level tract of land possessed by the airport. For one reason or another, an average of about ten airports per state die each year. Based on a recent survey, it appears that 800 airports were lost in 1957-58.

Now some communities have done something about this problem.

In the Denver area, Jefferson County is planning an airport for general aviation aircraft with relatively simple but adequate facilities. The Minneapolis-St. Paul Metropolitan Airports Commission operates five secondary airports to service general aviation. Chicago, which ten years ago had 37 airports serving the area, today has 29 and is engaged in a major study of the problem, precedent, it is hoped, to remedial action.

We are now short on the order of 1,000 secondary airports and flight strips to service properly aviation growth. In the next ten years we will need on the order of another 2,000. (Some would raise these figures, but our geography and communities will be pretty well covered by these and further growth will be covered by expansion of these airports.) Here we are looking at a billion dollar market.

Let us now turn to the big airports since they are a key part of our structure. We are talking of airports having runways of 5,000 to 6,000 feet and over, of heavily constructed runways and taxiways, large land requirements, and of a complex of terminal facilities. The FAA lists about 700 airports in the big classification.

We can expect that the number of such airports will not be increasing very much. We are already serving most of the geographical communities that need such service; and while the planes involved will become bigger, will be carrying more people and carrying them faster, the total fleet size as we indicated before will increase only modestly, if at all.

With 700 big airports, we would have airports spaced about sixty miles apart if evenly spaced across our country. Of course they are not evenly spaced since population and the resulting air transportation demand is not evenly spaced. The government names about 180 identified metropolitan areas. We use some 290 traffic generating centers in our work. In any event, we can see that our present 700 big airports can service a good bit of geography for the airlines.

General aviation can use the big facilities, but when they do use them, say a runway, they blank out capacity for the air carriers. A 10,000 foot runway has to be kept clear for landing a Cessna 172 just as much as for landing a Boeing 707. Here we have an opportunity to increase the operational capacity of our larger airports at only moderate cost simply by developing new patterns which will accommodate general aviation aircraft.

This is a problem in airport layout, one for the civil engineer. Why not use some short runways of lighter construction? Maybe we have to have separate traffic patterns—maybe even a separate taxiway system.

Why not consider bringing general aviation planes closer to the terminal? If this is not possible, why not devise a means to bring the passengers of these aircraft to the terminal building in short order?

And so we have another clear design in the pattern of the future—that of major modification and expansion of large airports, but no significant increase in their number. And with it the need, again, to accommodate general aviation.

By 1970 we expect a doubling of passenger traffic. The quick assumption is made that our airports will be twice as crowded as they are today. But facilities must accommodate peaks, not averages. Here is the heart of a problem. With elapsed flight times decreasing between points A and B, passengers will more and more be concerned with departure and arrival times. In effect, the airplane moves towards becoming a commutation device. No longer will business men set aside an entire day to make, say, a transcontinental trip. This means that schedules will tend more and more to peaks.

The view of this, at least on a weekly basis, has probably been experienced by all of us who have tried to get Friday night air reservations. And bad as these rush hour peaks can be, they will be made worse by the larger number of passengers each aircraft will be carrying. Today's unloading of 30 or 40 people will be tomorrow's unloading of 100 to 200.

If, taking today's requirement as a base, we plan to double our peak-hour passenger handling capacity in the terminal, we are making a mistake. I would put the increase at a factor of four because of the anticipated peaking effect.

The last design in my pattern has to do with the planes of the future and their effects on airport design. Two points are suggested. First, the creeping growth of runway length is going to stop. Public and community reaction to the cost and land use will cause this. Second, the advent of VTOL/STOL aircraft is not going to modify airport requirements for some time. This is true because it will take some years before they are common and, more importantly, because the conventional aircraft of today has become a pretty efficient load carrier. It's simply cheaper to run along the ground to gain lift for your load than to go straight up. So, as far as airports are concerned, the conventional fixed-wing plane of today will condition your design for the foreseeable future.

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ENVIRONMENTAL PLANNING OF FUTURE AIRPORTS AND AIR BASES

S. Richard Rio[1]*

About three years ago in anticipation of the introduction of commercial jet airplanes, the operators of civil airports, and those people who have an interest in the areas surrounding the airports, became concerned about the impact that this new type of aircraft would have on the airports and on the surrounding communities.

When the Air Force first reviewed the airfield criteria, consideration was given to revising the glide angle from 1 on 50 to 1 on 100. Consideration was also given to runway lengths up to 30,000 feet. Thought was given to placing all housing facilities at least two miles distant from the runway, and even to the abandonment of existing runways and of reconstructing them to a different orientation in order to avoid flight over populated areas.

If we apply the factors of noise, of increasing passenger volume, and of air safety against the airfield's function and location, we note that environmentally speaking:

a. The volume of noise per take-off should be greater around air bases than at civil airports, but the effect of noise should be more pronounced around civil airports. This is because civil jets will utilize noise suppressors, whereas the military aircraft do not use suppressors, as these devices degrade the performance of the aircraft. This degradation is acceptable to civil carriers, but is not countenanced by the military organizations. Efforts are being made to develop a suppressor which will be acceptable for military use. The degree to which jet noise will be accepted around civil airports has not yet been fully tested. If all forecasts on passenger volume come true and if more reliance is given by the military to rockets and missiles, the frequency (intervals) with which the areas surrounding the airfield will be subjected to this noise should increase at civil airports and decrease at military bases. However, the variables are such as to prevent any firm conclusions. For instance, passenger volume is increasing, but so is the load-carrying capacity of the aircraft. Which one will outstrip the other? It could be

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* Slides were used to illustrate Mr. Rio's presentation.

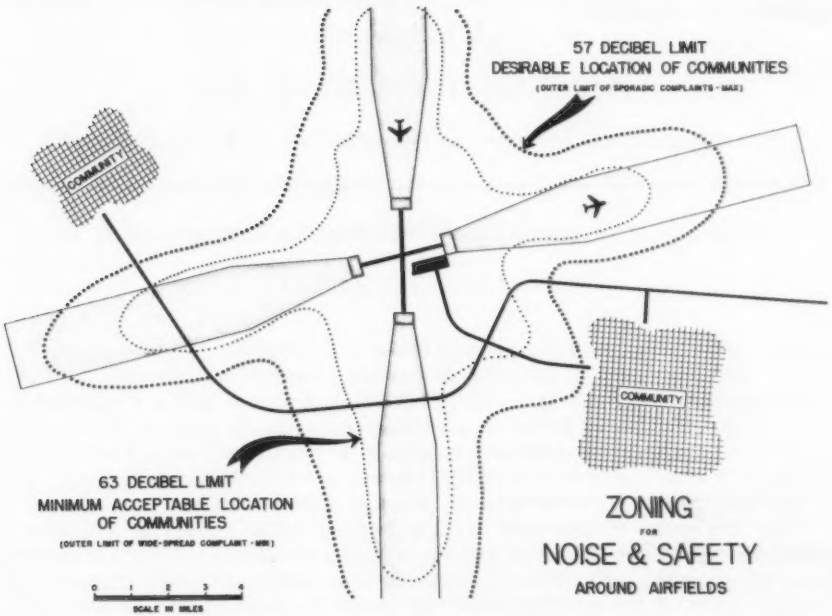
that, because of the increased passenger-carrying capability of the aircraft, fewer flights may accommodate the increased passenger load. On the military side of the "picture," it is conceivable that the airplane will lose some of its importance as a weapon, but may be needed to a greater degree than today to give logistic support to the missile bases. The amount of air traffic generated by the military organizations may decrease; and, the use of presently available noise suppressors may be permitted.

b. The military installation is not confronted with the large, steady, and increasing flow of automobile traffic generated by commercial aviation passengers. The military base is, however, confronted with two daily peak loads. Both the airport and the air base generate a need for improved highway networks. The extent of improvement will depend on the individual airfields. Some air bases, such as Wright-Patterson and Cape Canaveral, impose extremely heavy traffic loads throughout the day, with morning and evening peak loads. By and large, these are the exceptions. In general, automobile traffic will have a more telling effect on the highway systems around airports than around air bases.
c. Both types of installations, in order to achieve safety in flight operations, require that the land under the approach zones be controlled. This control is one of land-use and of height of structures.
d. Both types of installations generate a considerable development of real estate in their vicinities. The nature of this development differs. Around military installations it is of a personal services type; whereas, at civil airports it is principally of a light industrial and commercial type. In this respect, the major amount of construction activity will be around the civil airports.
e. Relative to the furnishing of utility services, increased demands will be made on these services by both civil and military airfields.

If we combine all of the factors that have been mentioned, we then develop a single, over-all problem—that of compatibility between the airfield and the neighboring communities. This, either because of an inability to enlarge the airfields to handle the type and volume of traffic or because of resistance by the neighbors to the noise and dangers associated with airfields, may force the development of new airfields on locations more remote from the cores of the cities. For civil airports, this raises the question of on-ground transit time from city terminal to airport. It is definitely incompatible with the airlines' efforts to reduce the time required to get the passengers from portal to portal.

The final question becomes that of how to control the environmental development in light of the factors that impinge on the environment and in light of what we expect to happen.

If we depict the various factors on a map, showing the airfield and its surroundings, we develop a portrait (Fig. 1) showing the extent of influence of these factors. Flying safety and noise create an envelope, enclosing a large mass of land immediately adjacent to and surrounding the airfield, while vehicular traffic necessitates a series of lanes. The relationship of these factors to the surrounding communities can then be studied and appropriate measures, such as re-orientation, selective use, or complete relocation of runways, can be considered. In conjunction with this analysis, zoning of all the land around the airfield and along the new highways should be accomplished



in coordination with any existing zoning ordinances. It is utterly impossible for any agency, military or civil, to acquire rights to all of the land that is adversely affected by aircraft movements. In recognition of this fact, and in further recognition of the fact that the air base and the surrounding community are interdependent, the Air Force, in order to promote an harmonious environment, has established some rather generous criteria for the selection of our air base sites. It is felt that these criteria will serve and protect all interests.[2] Instructions have also been issued to all air base commanders to cooperate with the local officials in the development of mutually beneficial zoning ordinances.

These, then, are the means for controlling the environment. The shape that this environment will take is conjectural. It is evident, however, that ample space under appropriate land control is needed to insure that the aircraft segment of the transportation industry does not receive the criticism that is being increasingly leveled at our confrères, the highway engineers—that is,

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2. a. The site shall be at least 15 miles from the planned expansion limits of a support city of at least 25,000 population.
   b. The extended centerlines of the runways shall not pass within four miles of the edge of built-up portions of communities within ten miles of the site, if such built-up portions exceed a population density of 1,000 per square mile with a total population of at least 500 people.
   c. Insure that no residences and places of public assembly, or areas of a "sensitive" nature are located within an area four miles wide by seven miles long off the ends of the runway systems.

that the total needs of the communities are being made subservient to the needs of the automobile.

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INTEGRATING THE AIRPORT INTO METROPOLITAN PLANNING

Philip E. Geissal[1]*

This discussion is limited in location to a typical great plains city, Kansas City, Mo. Here as we integrate the airport with the metropolitan plan for Greater Kansas City we must strive for greater acceptance of controls for orderly development which can be proven to be in the public interest.

Greater Kansas City is a five-county metropolitan area astraddle of the state line between Missouri and Kansas containing two major cities of Kansas City, Missouri and Kansas City, Kansas. It is anticipated that by 1980 approximately one-third of the 5-county area of 2000 square miles will have grown out from the two Kansas City's to form an urban area of approximately 660 square miles. The urban area of Greater Kansas City accounts for about 90% of the population in the 5-county metropolitan area and it is anticipated that this population within the urban portion will increase from 960,570 in 1957 to 1,340,200 in 1980.

Kansas City has grown rapidly since the opening of the Municipal Airport in 1927. This facility located less than 5 minutes from the Central Business District in 1957 handled over one million six hundred thousand passengers. With 8 commercial airlines serving Kansas City, with direct connections to other urban areas, Kansas City is ranked 11th in aircraft operations (scheduled airlines and itinerant planes) and 16th in enplaned passengers. Kansas City's position in aviation has been greatly enhanced and its continued importance assured by the establishment of a second major airport, the Mid-Continent International Airport, which is also owned and operated by the City of Kansas City, Missouri. The two federal airports, Richard-Gebaur Airport, headquarters of the Central Air Defense Force 20 miles south of Downtown Kansas City and a former municipal airport; and the Olathe Naval Air Base, are located just outside the 1980 urban area but within the metropolitan area. Considering employment in manufacturing of aviation equipment, in federal aviation supervision from Kansas City, in airline activities and operation of the four major airports, the total employment in aviation activities in Greater Kansas City in 1957 was in excess of 21,000, or approximately 5% of the grand

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* Slides were used to illustrate Mr. Geissal's presentation.

total of employment in the metropolitan area. It is anticipated that this total employment in aviation will be expanded by 12-15 thousand by 1980.

The new Kansas City Mid-Continent International Airport was acquired by Kansas City in 1953 and 1954 at the time that the Grandview Municipal Airport was made available to the Air Force for Richard Gebaur Airport. It is a site of 4600 acres which was selected after a careful review of alternate sites in relation to air traffic patterns of the Municipal Airport; the then operating adjoining Fairfax Airport directly north across the river from Municipal Airport, the Richard-Gebaur and Olathe Airports. A strong topographic control of the river valleys in our areas forced the selection of a new site north into the upland area of Platte County. This is fortunate in that a rural oriented county which has been arrested in urbanizing because of lack of adequate highway river bridge crossings, thus provided a somewhat virgin area in which the pattern of urban development could be guided after the location of the airport was established. The airport has been developed with a north-south runway of 6000 feet, which is now being extended to 9000 feet. An east-west taxiway at the south end of the runway provides access for the TWA Overhaul Base which is the first tenant of the property at the southeast corner of the site, as the first stage of developing aviation oriented industry in a planned relationship to the future operating airport. Though the full development plan for terminal facilities is still being developed, the east-west taxiway serving the TWA Overhaul Base parallels the location of the proposed future east-west runway and the terminal facilities will be constructed north of the east-west runway and between the existing and future north-south runways.

Our City Plan staff developed data for a traffic consultant who had the job of expanding traffic information secured, in a 1957 origin and destination trafficway survey, to forecast zone to zone traffic movements anticipated in 1980, and then assign these traffic movements to the freeway and major thoroughfare system. Therefore, it was essential that we develop an anticipated pattern of future land use for a 1980 urban area, the outside limits of which became the cordon area for the "internal trip" traffic analysis. Thus with a future land use pattern fixed we also provided the zone by zone information on 1957, and estimated 1980 redistribution of population and employment; persons in labor force; volume of retail trade; and relative income levels in residential areas.

Such study shows the suburban growth that is anticipated within the limits of the 1980 urban boundaries whereas the old established central cities of Kansas City, Missouri and Kansas City, Kansas will grow very little within their old limits, although Kansas City, Missouri has met the problem with an aggressive program by extending its corporate limits. The unincorporated areas in Clay and Platte Counties within the 1980 urban area are within future annexation proposals of the City and thus the Mid-Continent International Airport and tributary area would be taken into the City's service areas. Because of the relative drawing power of other portions of the urban area, the population growth in the Platte County urban area adjoining the airport from 11,178 in 1957 to 41,625 in 1980 is a conservative 30,337. Therefore, it appears that the immediate danger of overrunning the airport with suburban growth is slight. (This anticipates that in accord with national trends there would be an overall increase in the 5-county metropolitan area from approximately 1,000,000 to 1,450,000 from 1957 to 1980.)

The study disclosed the 28 major centers of employment as they existed in 1957 within the 1980 urban area. These are the major industrial, commercial

and public and semi-public districts, which are expected to continue to be the dominant pattern in 1980. In 1957 these districts accounted for an employment of all types of approximately 270,000, which represents about 80% of the 340,000 which is the 1957 employment within the anticipated boundaries of the 1980 urban area. By 1980 it is forecast that employment within these 28 major centers will increase from 270,000 to approximately 360,000 for a gain of 33% increase over the 1957 employment. (There are about 45 other centers old and new distributed throughout the 1980 area but principally on the periphery. These are lesser centers, primarily retail, planned industrial, or cultural in character, which have a potential for development by 1980. They will account for 12 to 15% of the total of all types of employment estimated to be 465,000 in 1980 in the urban area.)

Employment at Mid-Continent International Airport is primarily at the TWA Overhaul Base in 1957 and accounts for 4000 people. It is estimated that the development of administrative, recreation and service functions of a fully operating airport, and the further growth of specialized or controlled industries will increase the employment to 11,000 to 12,000 by 1980.

The importance of the Central Business District is pointed out, which was the #1 place of employment in 1957 with 66,000 and which, it is estimated, will provide employment for 85,000 by 1980. This is the area within the Central Business District Freeway Loop and freeway construction and redevelopment projects are well advanced to assure the continued prosperity and development of the Central Business District.

Another 80,000 to 100,000 workers are located in adjoining commercial and industrial districts within a 3-mile radius of the 100% block in the heart of the Central Business District. As this accounts for over half of the employment in the entire urban area in 1957 and it is anticipated that this relationship will be maintained in 1980, these areas provide the principal generator for traffic to and from the Municipal Airport as well as the Mid-Continent International Airport.

Thus we see that we have the extremes of coordinating land use patterns. The Municipal Airport, one extreme, 3 to 5 minutes from the center of downtown, with a 7000' runway extended the full limits of the restraining river levees, and flight lines in tight relationship to the Central Industrial District and high structures, high value, central core of the city; and the other extreme of a Mid-Continent International Airport set down in an undeveloped area where advance planning and adequate controls can prevent a reoccurrence of such conflicting conditions.

Kansas City's central location in the United States again is favorable as parts of designated federal Interstate Routes provide five radial freeways from the periphery to the Central Business District. The designation of a Circumferential Freeway on the federally supported interstate system also improves the time distance for crosstown movements to the new Mid-Continent International Airport. The Municipal Airport is only 3 to 4 minutes from the center of the CBD or the City Hall, by use of the completed intercity freeway and new limited access Broadway Bridge and approaches. The freeway construction is nearing completion in Clay and Platte Counties north of the river and the Mid-Continent International Airport has direct access by freeway from the CBD. Though slightly over 14 miles by airline the Mid-Continent International Airport is 16 miles by freeway, but can be reached in just a few minutes. The Municipal Airport and Mid-Continent International Airport are

12 miles apart but will be joined by freeway upon completion of another link in the urban system.

Preliminary master planning has been carried forward by the City Plan Commission staff in Clay and Platte Counties, for the Missouri area north of the Missouri River. These studies of land use and transportation needs were started about 12 years ago. The first annexation by Kansas City, Missouri, of a 19-square mile area in Clay County, took effect in 1950. However, planning units cannot conform to the minor political boundaries of corporate areas, so while the corporate area was planned more intensely, a broad guide plan has been prepared for the future 1980 urban area of Clay and Platte County. In developing a skeleton pattern for the relationship of the airport to the other uses, it was apparent that residential communities will develop as each community is made up of a number of neighborhoods centered around the elementary schools. Industrial land area is concentrated in North Kansas City and in other river valley districts, and in the decentralized Claycomo industrial area. It is contemplated that a planned industrial park of 1500 to 2000 acres can be developed immediately south of the Mid-Continent International Airport and served by the same Interstate Freeway which serves the airport.

However, such district would not be extended west into the approach planes or transitional planes of the runways at the airport. The master plan indicates holding the approach planes of both the north-south and east-west runways in a non-residential or agricultural use. It is believed that zoning control and refusal of approval of subdivision plats in these areas can protect them for the next few years against development, though it may be necessary eventually to recognize the need to control these areas through payment of development rights, offer tax abatement or develop portions of the areas in acceptable public or semipublic uses. As previously noted the land in the approach zones to the south and southwest of the airport north-south runway is very rough topography and not readily adaptable to tract development. This is not true of an eastward projection of the east-west runway. However, as this is generally high ridge land on the divide and therefore at the upper reaches of two watersheds, sanitary sewer assessment costs would be high and this may assist in holding land out of development.

Before the Mid-Continent site was acquired in 1953 and 1954, the right of establishing county zoning was secured for Platte County. A County Plan Commission was founded and a Zoning Order of the County Court was adopted in September of 1954. Representatives of C.A.A. worked with Kansas City in making recommendations to the County on providing adequate zoning protection for Mid-Continent International Airport. The adopted ordinance provides through Sec. 21 District A-V "Airports" for zoning control for primary and secondary airports. It further provides that no other airport shall be located within 8 miles of a primary airport. Though a number of ordinances handle land use and height controls by reference to federal regulations, the height and use controls are spelled out in this section of the Platte County Ordinances.

In order to maintain a compatible ground use relationship of uses on the airport site with less intensive uses on adjoining land a 1/8 mile border around the site is held to residential uses or other uses allowed on adjoining land as a buffer for the more intensive industrially classified uses allowed on the remainder of the site. This is a commonly applied technique in the planned industrial district and Kansas City concurred in this provision for the

Municipally owned Mid-Continent International Airport in the interest of maintaining good relationship with abutting uses.

As we enter the Jet-Age of Commercial Air Transport there may be new problems of "integrating" the air transport use with other land uses, but it would seem that here again a continuity of the planning function, when based on a knowledge of the old but also on an awareness of the changing urban pattern, will make it possible to up-date the guide plan.

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GROUND TRANSPORT OF PEOPLE TO AND FROM THE CIVIL AIRPORT

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SYNOPSIS

This paper discusses the ground transportation of air passengers, visitors and employees between large civil airports and the communities they serve. The locations of airports within the communities, travel desires and modes of travel of people going to and from the airport are all examined. Relevant information pertaining to 25 large airports in the United States and 25 in other countries is presented. There is a concluding discussion of the implications of this topic to a community concerned with the ground access to its airport.

The Topic

A typical journey by commercial air transportation actually involves the use of a series of interrelated travel modes (Fig. 1).

With the increasing speed of commercial aircraft and consequent shortening of travel time between airports the percentage of the total origin to destination journey time spent on the ground is becoming steadily larger. Already on such trips as Manhattan to downtown Boston or the Chicago Loop, or from downtown San Francisco to the Los Angeles Civic Center, half of more of the time is spent thus, going to and from the airports. When commercial air travel will reach speeds of Mach 3 this disproportion will become still larger and even on transcontinental or intercontinental flights the initial and final ground stages will require a major portion of the journey time. In addition to the passengers the needs of the many other people going to and from the airport must also be considered. It, therefore, seems worthwhile to examine this very necessary and time-consuming part of the total air transportation system. In this paper the authors present a general analysis of the ground

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AT 3

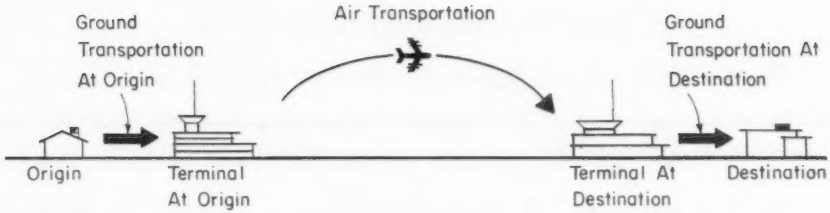

Figure I The Air Transportation System

transport problem, supported by data gathered from numerous airports here and abroad. This study will exclude transportation of goods and will be focused on large cities.

Data Collected

Fifty large airports were selected, 25 in the United States at cities classified as "large Hubs" by the Federal Aviation Agency, and 25 in other countries on all continents (see Tables I and II). A questionnaire directed to their managers brought almost 90 per cent replies, many in considerable detail or with much supporting material. There was additional correspondence with these officials, as well as with other public agencies, consultants, etc., supplemented by personal interviews and first-hand observations by the senior author at many of the airports, both in the United States and elsewhere. Most of the collected information was general in nature and did not lend itself to statistical analysis. The tables presented in this paper summarize much of the pertinent numerical data. Many airports had no numerical data on ground transportation.

One inescapable conclusion is that only a few cities have made systematic, detailed analyses of the characteristics of ground transportation travel to their airports, which seems somewhat surprising in view of its essentiality and of the large sums of money being spent or planned to be spent on providing transportation links to various airports.

Location of Airports

By their nature airports require a lot of land; in all but a very few cities it has been necessary to go some distance out to find sufficient space, with many more recent airports being located ever farther away from the community's center.

Distances from the central business districts to airports in the United States (Table I) range from 2 to 30 miles, with a typical order of magnitude of 7 to 17 miles. Elsewhere (Table II) they range from 3 to 21 miles, with most

Table I
Distances and Travel Times
Airports to Central Business Districts

Table I

Distances and Travel Times

Airports to Central Business Districts

UNITED STATES

City	Airport	Distance from Central Business District (Miles)	Travel Time from Central Business District (Miles)
Atlanta	Municipal	9	15
Boston	Logan International	3	20-40
Chicago	Midway	10	40-60
Chicago	O'Hare	23	50-65
Cleveland	Hopkins	14	35
Dallas	Love	7	25-30
Denver	Stapleton	7	15
Detroit	Metropolitan	17	25
Detroit	Willow Run	30	45
Houston	International	10	20-30
Kansas City	Municipal	2	5
Kansas City	Mid-Continent	16	a
Los Angeles	International	14	60
Miami	International	7	15-30
Minneapolis-St. Paul	Wold-Chamberlain	9	25-30
New Orleans	Moisant International	13	40
New York	International (Idlewild)	15	30-45
New York	LaGuardia	8	30
New York	Newark	12	30
Philadelphia	International	6	15-25
Pittsburgh	Greater Pittsburgh	16	25
St. Louis	Lambert	15	35-50
San Francisco	International	14	25-30
San Juan	Puerto Rico International	10	15
Washington	National	4	15-30
Washington	International	24	40-50a

Note (a) - Airport in planning stage.

Table II

Distances and Travel Times

Airports to Central Business Districts

NON-UNITED STATES

City	Airport	Distance from Central Business District (Miles)	Travel Time from Central Business District (Miles)
Amsterdam	Schiphol	7	20-25
Berlin	Templehof	3	15
Brussels	National	8	20
Buenos Aires	Ezeiza	21	60
Caracas	Maiquetia	16	35
Copenhagen	Kastrup	5	15-20
Frankfurt	Rhein-Main	8	30
Geneva	Cointrin	3	15
Hong Kong	Kai Tak	5	15-25
Johannesburg	Jan Smuts	15	25
Lisbon	Portela	4	10-30
London	Central and North	14	50
London	Gatwick	20	50
Mexico City	Central	4	15
Montreal	Dorval	12	30
Moscow	Vnukova	4	40
Paris	LeBourget	8	30-45
Paris	Orly	8	25-40
Rio de Janeiro	Galeao	9	30
Rome	Ciampino	11	30
Sidney	Kingsford Smith	6	20-30
Stockholm	Bromma	6	15-20
Tokyo	International	11	50
Zurich	Zurich	7	20

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of them from 5 to 15 miles away. Corresponding travel times are in the order of 20 to 50 minutes or more in the United States and 15 to 40 minutes in other countries.

Travelers to and from Airports

Three distinct groups of people require transportation between the airport and the community it serves:

Passengers
Visitors
Employees

In all cases, by definition, one end of their ground trips is at the airport. The other ends, it will be seen, are not at such a single defined point or small area.

Origins and Destinations

Passengers

Air passenger travel can be divided into two categories:

Personal
Business

Each air passenger going to or from the airport on the ground is at one of two places, his:

Home city
Destination city (some city other than home city)

Trips of people traveling for such personal reasons as family visits, recreation, sightseeing, etc., most probably originate at their home, which may be located anywhere within the community. Only a small number will be living in or close to the central business district or have a desire to pass through there on the way to the airport. At the destination city the personal traveler may go to a home in any part of the community, or to a nearby recreational area, and only in some cases to a hotel in the central business district.

Business travelers at the origin city may proceed to the airport either directly from their home or else from their office, which may be in the central business district or otherwise, with the steady suburbanization of industry, somewhere else in the community. At the destination city they will go to a place of business either in the central business district or perhaps in a decentralized location. Upon return to their city of origin they may go to their office, but frequently such return will be after business hours and they will proceed directly home.

Visitors

Visitors to the airport going for sightseeing, entertainment, to patronize restaurants or to bring (or fetch) air travelers will probably not leave from or return to a place of business, especially not on weekends, but rather will come from and return to their home, located anywhere in the community, most likely not in the central business district. While many of them will be in a

hurry, many others will not be particularly pressed for time and may be more interested in comfort and convenience, as, for example, on a family outing.

Employees

Large airports have many employees. Only a few are flight crews, who at their home city will live anywhere within the community and only in a layover city will perhaps go downtown for a hotel, unless they prefer to lodge nearer the airport. For the great majority of employees, their origins and destinations within the community will be their homes, again located anywhere within it.

An analysis based on logic, therefore, leads to the conclusion that most ground travel to and from airports is to and from origins and destinations dispersed throughout a community, with only a minority of such trips being to and from the central business district.

Origins and Destinations—Data

The data obtained confirmed the foregoing reasoning. Such statistics as were available are presented in this paper as follows:

Location	Passengers	Visitors	Employees
Boston			Table XV
Cleveland	Table X		
Minneapolis-St. Paul	Table IX		
New York (3 airports)	Table VII	Table XIII	Table XVI
San Francisco	Table VIII		
Amsterdam		Table XIV	
London (2 airports)	Table XII		
Paris (2 airports)	Table XI		

General comments, opinions, estimates and partial statistics were sent by these and numerous other cities. All were along similar lines . . . and all this evidence was in line with the analysis previously presented.

The conclusion is inescapable: For all three categories of people traveling between an airport and the community it serves, passengers, visitors, and employees, their origins and destinations within the community are widely scattered, with in the order of 40% of the passengers and much less of the total of all categories of people going to or from the central business district.

Origin and destination studies of a large city typically show strong trip desires connecting the central business district and all parts of the community. It appears that a similar pattern exists for travel to and from the airport. It has also been shown that the typical large city airport is located at a considerable distance from the central business district, often near or beyond the edge of the community. These two patterns might be illustrated diagramatically as follows (Fig. II):

It can thus be inferred that only in some cases will the desire lines to a central business district and to an airport coincide; for most trips they will be quite different. This would appear to be significant to all cities planning ground transportation modes, facilities and routes to serve their airport.

The next step will be to analyze ground travel modes.

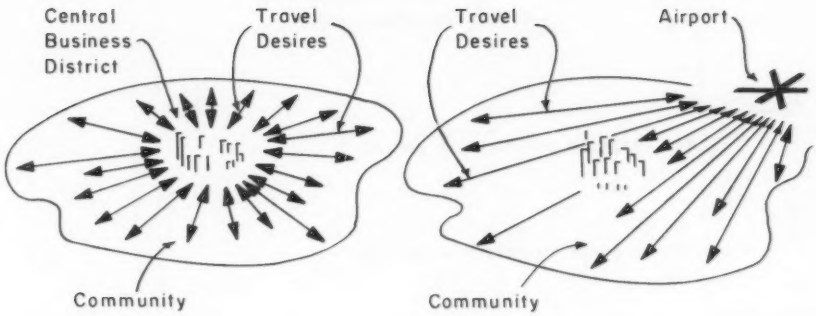

FIGURE II SCHEMATIC DESIRE LINES TO CENTRAL BUSINESS DISTRICT AND AIRPORT

Ground Travel Modes

It has been shown that the typical airport is located to one side of the community it serves, and that the desire lines for ground travel from it extend to all parts of the community.

This appears to suggest that the most used ground transportation modes will have to be types that can best cope with this diffuse pattern. Mass transit should be least able to do so unless its route also coincides with some other strong community desire line; the limousine somewhat more, as its passenger volume-price relationship is much more favorable, and the automobile and taxi should be the most suitable of all.

The evidence strongly corroberates this analysis. Table III shows that the private automobile, taxi and limousine are used at almost all airports from which data were obtained. Public transit busses operated to 80 per cent of them. On the other hand, there were passenger-carrying rail facilities at only a very few airports, only one in the United States. Scheduled helicopter service, in effect a substitute for ground transportation, was provided in only four of the communities studied.

Detailed numerical data as to modes used by air passengers were available from several cities (Table IV), and from a few cities as to the modes used by visitors (Table V) and employees (Table VI).

Passengers

Only at London-Gatwick did a majority of air passengers use rail transportation to reach the airport. Brussels had almost a third such use. In other cities almost all air passengers arrived at the airport in a rubber-tired vehicle, and in most cases in one providing personalized transportation, the

Table III

Ground Transportation Modes Available to and from Airports

(50 cities examined)

Automobile

All Airports in Tables I and II

Taxi

All Airports in Tables I and II

Limousine

All United States Airports in Table I

Almost All Non-United States Airports in Table II
(operated by the airlines themselves at about 2/3 of these cities)

Public Transit Bus

80% of Airports in Both Tables I and II

Rapid Transit and Railroad

Boston
Berlin
Brussels
Johannesburg
London - Gatwick
Stockholm
Tokyo

Scheduled Helicopter

Chicago
Los Angeles
New York
Brussels

Table IV

Passengers - Travel by Mode

(for cities furnishing data or estimate)

City	Percentages Using Each Mode							
	Auto	Taxi	Limousine	Public Bus	Rapid Transit	Rail-road	Scheduled Helicopter	Other
UNITED STATES								
Cleveland	57 b	14 b	27 b	1 b				1 b
Dallas	55	22	20	2				1
Houston	74	26 a						
Minnespolis-St. Paul	59 b	23 b	18 b	0 b				
New York-International	42 c	26 c	31 c	1 c			d	
New York - LaGuardia	37 b	41 b	20 b	2 b			d	
New York - Newark	46 b	12 b	38 b	4 b			d	
Washington - National			32 a					
NON-UNITED STATES								
Amsterdam	e	e	45-50 a	e				
Brussels						30 f	d	
Frankfurt	48		49					
Hong Kong	g	g						
Johannesburg	30 a		70 a					
London Central-North	41 b	5 b	50 b	4 b				
London - Gatwick	24 b	1 b	6 b	0 b		69 b		
Paris - LeBourget	12 h	64 h		22 h				2 h
Paris - Orly	14 h	63 h		20 h				3 h
Sidney	25 a		75 a					

a) Estimated
b) Emplaning Passengers Only
c) Domestic Emplaning Passengers Only
d) Less than one percent
e) Estimated 50-55% Use Auto, Taxi and Public Bus
f) Estimated for Those Passengers Having Origin or Destination in City of Brussels
g) Majority Arrive and Depart by Auto and Taxi
h) Travel Mode to and from Invalides In-Town Airline Terminal

Table V

Visitors - Travel by Mode

(for cities furnishing data or estimates)

City	Percentage Using Each Mode				
	Auto	Public Bus	Sightseeing Bus	Bicycle & Motorcycle	Excursion Boats
New York-International	100 a				
New York-LaGuardia	100 a				
New York - Newark	100 a				
Amsterdam	49	17	24	9	1
London Central-North	71	10	15	4	

a) Estimated.

Table VI

Employees - Distribution by Mode

(for cities furnishing data or estimates)

City	Percentage Using Each Mode				
	Auto	Public Bus	Auto or Bus	Bicycle	Other
Boston	93 b	7 b			
Minneapolis-St. Paul	89	6			5
New York-International	87	9	3		1
San Francisco	74 c	17	9		
Amsterdam	5 a	70 a		20 a	5 a
Sidney	40 a	d			
Tokyo		e			

a) Estimated
b) Estimated Usage by Northeast Airlines Employees
c) Drive Alone 46%, Carpool 28%
d) Estimated Principal Modes Are Public Bus and Auto
e) Most Employees Use Public Bus

private automobile or the taxi. Limousine services provided such transportation for a sizable percentage of air passengers, though in most cases less than half; there was almost no data except from Paris as to how passengers reached the starting points of the limousine services. Those cities with high limousine patronage appeared to have low taxi patronage, which suggests that significant differences in costs between the two may have had an important effect on choice.

Noteworthy was the similar use of personalized private automobile and taxi transportation in non-United States cities, even in countries with strong

Table VII

Origins of Emplaning Passengers

New York Airports

County of Origin	Percentage of Passengers		
	International	LaGuardia	Newark
Manhattan	47	53	38
Brooklyn	10	6	3
Queens	9	8	2
Bronx	4	3	2
Nassau	10	9	1
Westchester	4	5	2
Essex	1	1	14
Union	1	1	8
Bergen	2	3	6
Hudson	1	0	3
All other counties	11	11	21

Table VIII

Origins of Emplaning Passengers

San Francisco International Airport

County of Origin	Percentage of Passengers
San Francisco	56
Alameda	14
San Mateo	12
Santa Clara	11
Marin, Contra Costa, Solano, Sonoma, Napa	6

Table IX

Origins of Emplaning Passengers

Minneapolis - St. Paul - Wold-Chamberlain Field

Origin	Percentage of Passengers	
	Minneapolis	St. Paul
Loop Areas	38	8
Areas Surrounding Loops	40	14

mass-transit vogues. An interesting difference was that whereas here limousine service is usually provided by a specialized operator, in 2/3 of non-United States cities the airlines furnished this service themselves. Several airports abroad not furnishing figures commented that a significant percentage of air passengers did not use these limousine services even when they were provided free. Some evidence was available that with the passage of years the limousine, while holding its own volumewise was slowly losing percentagewise in number of air passengers handled.

The figures show that the public transit bus had small acceptance everywhere by air passengers; personal observation is that in most cities a passenger would be hard-pressed to accomplish getting to or from the airport by public transit.

Visitors

Little data on visitor transportation modes appears to have been collected, but such as could be found showed it to be almost entirely rubber-tired, with sizable percentages in Amsterdam and London coming by transit or sightseeing bus.

Employees

Again, little data has been assembled by various cities that were contacted, but what there is shows the automobile to be the largest single mode in the United States and the public transit bus elsewhere.

To summarize, it appears from such evidence and opinion as is available that rubber-tired modes are predominant in providing transportation to and from an airport for all categories of people using it. In the United States the private automobile is pre-eminent, with the taxi and limousine also significant in handling the air passenger portion of the total ground travel. Elsewhere these three modes are all significant for air passenger transportation whereas for visitors and employees a more significant role is played by sightseeing busses and public transit busses respectively.

It might be asked whether people went by automobile because they preferred this to other modes or whether the other modes were so inadequate that they had to drive. No doubt the latter was true for many individual trips. In the aggregate it may not have been, especially for passengers, as shown by the data included in this paper.

Rail Transportation

Only a few cities have rail passenger links to their airports. In Boston, the only United States city with such a facility, actual counts by the operating agency have shown travel at the airport subway station to be very small. As already noted rail has worked well at London-Gatwick and Brussels National; at both these airports existing trackage could be used. The Gatwick terminal, for instance, is directly over the heavily traveled London-Brighton line. West Berlin has a subway station at the terminal door, but no statistics have been collected as to the amount of use by each category of the airport population, and in any case its city-state character makes transportation there unique. In a number of other cities rail links to the airport have been considered. In Amsterdam and Copenhagen these may someday materialize in the form of

Table X

Origins of Emplaning Passengers

Cleveland - Hopkins Airport

Origin	Percentage of Passengers
Cleveland-Central Business District	39
Remaining City of Cleveland	13
Other Cleveland Postal Districts	23
Remaining Cuyahoga County	5
Other Counties	20

Table XI

Origins and Destinations of Passengers

Paris Airports

Origin	Percentage of Passengers	
	Le Bourget	Orly
Central Paris	19	17
Northern Paris	10	12
Southern Paris	19	16
Eastern Paris	9	11
Western Paris	5	5
Paris (Location Unknown)	29	25
Areas beyond Paris	9	14

Table XII

Origins of Emplaning Passengers

London Airports

Origin	Percentage of Passengers	
	London - Central and North	Gatwick
Central London	35	14
Northeast Greater London	4	13
Southeast Greater London	5	14
Southwest Greater London	8	12
Northwest Greater London	12	12
Remaining United Kingdom	36	35

Table XIII

Origins of Visitors' Cars in Parking Lots

New York Airports

County of Origin	Percentage of Vehicles		
	International	LaGuardia	Newark
Manhattan	16	12	4
Brooklyn	19	11	3
Queens	21	23	4
Bronx	7	7	2
Nassau	10	16	1
Westchester	6	10	1
Essex	2	2	26
Union	1	0	15
Bergen	2	3	10
Hudson	1	1	10
All Other Counties	15	15	24

Table XIV

Origins of Visitors

Schiphol Airport, Amsterdam

Province of Origin	Percentage of Visitors
Amsterdam (city of)	20
North Holland (excluding Amsterdam)	23
South Holland	21
Brabant	8
Gelderland	8
Other 7 Provinces	14
Foreign Countries	6

Table XV

Residence of Northeast Airlines Employees

Logan Airport - Boston

City or Town of Residence	Percentage of Employees
Boston, including East Boston	23
Revere	7
Winthrop	7
Malden	5
Lynn	5
Somerville	5
Everett	4
Cambridge	3
Chelsea	3
Quincy	2
Wakefield	2
Other (all 1% or less)	34

Table XVI

Employee Residence

New York Airports

County of Residence	Percentage of Employees		
	International	LaGuardia	Newark
Manhattan	5	9	
Brooklyn	17	11	
Queens	45	50	
Bronx	3	9	
Nassau	23	15	10
Westchester	1	1	
Essex	0	0	41
Union	0	0	14
Bergen	1	1	6
Hudson	0	1	9
All other counties	5	3	20

stations on projected new major railroad lines primarily constructed to serve other points. Studies in Paris showed that developing rail lines to serve the airports there could not possibly be economically justified and expressway facilities will be provided instead. A similar economic conclusion was reached in regard to subway extension or monorail construction to London Central-North.

Summary

This paper has discussed the ground transportation requirements needed to link a community with its airport. Available evidence strongly supported this analysis. To summarize:

1. The airport is typically located well away from the central business district of the community it serves.
2. There are several categories of people who travel back and forth to an airport; air passengers, visitors and employees.
3. Their ground travel desires radiate from the airport to all parts of the community.
4. This travel is accomplished in most cities of the United States predominately by automobile, with taxi and limousine also significant in the case of air passengers, and negligible mass transit use by anyone.
5. In non-United States cities it appears that the automobile, taxi and limousine are also important for air travelers, the private automobile and sightseeing or mass transit bus for visitors, and the mass transit bus for employees.
6. Mass transit rail facilities have been provided at a few airports, usually as a part of a line also serving other points along and beyond; these facilities have not been uniformly successful as far as the airport travel is concerned.
7. Finally, it has been found that in most cities systematic studies including necessary data-gathering have not been conducted as to ground travel needs and desires at airports.

Implications

It is suggested that the analyses and findings of this paper have several important implications:

1. Fixed mass transit, such as rail, subway, or monorail, with its heavy costs per mile and considerable number of miles to be traversed, cannot be justified at the present time as a facility to serve the airport alone, either economically or in terms of actual use, as much of the travel to and from an airport has desire lines that do not coincide with it. Its best chance of success will probably be as a station on a longer radial line from the central business district to other high volume points, carrying considerable other traffic.
2. The predominance of rubber-tired transportation, when combined with the rapid air transportation growth rate and typical low passenger occupancy per motor vehicle emphasizes that airports have to provide efficient, large and expandable facilities for handling and parking vehicles.

3. In most cities a direct highway link into a community wide expressway system should be the best airport ground transportation link, as this will best serve the rubber-tired transportation.
4. The limousine operator is faced with a growing dilemma. Passenger travel desires require service to several parts of the community, but to be satisfactory service has to be frequent. This threatens to both increase costs and reduce load factors, creating economic problems.
5. In any case, it would seem that rational decisions about ground transportation should be based on facts. Few of the data necessary to develop such facts are available in most communities, even those now actively planning or building new and often expensive transportation links to their airports.

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Journal of the
AIR TRANSPORT DIVISION
Proceedings of the American Society of Civil Engineers

GROUND TRANSPORTATION

Robert F. Wall[1]*

A logical sequence in treating airline ground transportation might be found in the answers to the following questions:

1. What has been, and what will be, the growth of the airline industry.
2. What problems has this growth caused the ground transportation operators.
3. What has the airline industry recommended as a means of helping to solve these problems.
4. What has been accomplished.
5. What is the pattern for the future.

The growth of the United States domestic airline business is shown in Fig. 1. It is interesting to note that of the 703 cities served the majority of these are cities of less than 50,000 population. Ground Transportation problems are not exclusive to the large metropolitan centers.

Fig. 1

	1939	1949	1958
Number of Airlines	23	45	55
Aircraft in Service	347	1,083	1,900
Seats Available (Daily)	5,100	35,900	103,700
Number of Passengers Carried	1,864,000	16,723,000	49,075,000
Cities Served	286	638	703

A comparison of the past with the projected future is shown in Fig. 2.

Fig. 2. Domestic Airlines Revenue Passenger Miles
In Billions

1938	1948	1958	1965
.5	5.8	24.6	47.7

Note: Discussion open until December 1, 1959. To extend the closing date one month, a written request must be filed with the Executive Secretary, ASCE. Paper 2109 is part of the copyrighted Journal of the Air Transport Division, Proceedings of the American Society of Civil Engineers, Vol. 85, No. AT 3, July, 1959.

1. Supt. of Passenger Station Service, United Airlines, Inc., Denver, Colo.

* Slides were used with Mr. Wall's presentation.

To show how forecast volumes apply to specific cities let us consider the following:

At San Francisco, an average summer day in 1961, United Air Lines' Economic Controls group forecast that we will be boarding 4,100 passengers, At LAX, 4,000, and at the two Chicago airports, 4,500. These figures, based on our previous experience, will probably turn out to be quite conservative. When we add to these figures the passengers that all the other lines serving these airports will board, and when we consider that a comparable number will be deplaning, it is obvious that we have a large number of passengers to move in all forms of ground transportation. The airlines of the United States are spending more than $2,000,000,000 on one of the biggest re-equipment programs in transportation history. Airline seat capacity during this transition period will increase by approximately 40%. We obviously hope that the number of passengers using these seats will increase in about the same ratio. However, any overall projection of passenger volumes only tells a part of the story. The real demands on personnel coverage and equipment utilization are tied into what the airlines describe as "peaking." As an example, during the morning peak at SFC in 1961, our schedule calls for a jet peak of six airplanes at the gates simultaneously. Our peak for piston equipment will be nine airplanes. The maximum combination of two types of equipment will be ten airplanes in some stage of loading simultaneously. As early as next summer, six jet departures are scheduled out of O'Hare Field by United Air Lines within 40-minutes. Other airlines will be increasing their schedules correspondingly.

At New York's Idlewild Airport we estimate that by next summer between the hours of 4:00 p.m. and 7:00 p.m. there will be a movement of between 4,000 and 6,000 passengers for all airlines. This means a ground transportation capability will be necessary of between 800 and 1,200 passengers during the peak automotive traffic periods.

Secondly, let us discuss some of the problems which have faced the Ground Transportation Operators.

Airline ground transportation is a relatively new industry, but it is rapidly approaching the status of big business. Practically the entire development of this industry is confined to the period since the war. In the immediate post-war period, the airlines were operating a relatively few 21-passenger airplanes, and ground transportation was geared to this volume. Nine and twelve passenger "stretch out" limousines adequately provided for the demand. Special stops to meet the passenger's convenience were negotiated on an individual basis. City to airport running times were at the mercy of increased highway traffic congestion.

Many types of ground transportation exist to serve airline passengers—both competing with and complementing each others services. Some of these are listed below:

Taxi cabs must be made available in sufficient numbers to provide for the individual requirements of our passengers. Hire cars or livery service formerly occupied a prominent place at many of our airports, but their function seems to be dying out rapidly. The rental car industry is assuming an ever increasing place in our service to airline passengers. As an example, there are approximately 3,000 rental cars maintained at the Miami International Airport to meet the demands for this type of transportation. A large segment of the traveling public is either delivered to the airport or met at that point by private automobiles. These private cars represent the greatest threat to

the increased patronage and availability of franchised limousine service. To a lesser extent, municipal bus systems and commuter railways provide accessibility to the airport. The primary function of this class of service is to provide transportation for airport and airline employees.

Although not specifically classed as ground transportation, newly organized Helicopter Airways fulfill a similar function. Three major scheduled helicopter lines are in operation at Los Angeles, Chicago and New York City. Their business is increasing dramatically, and it appears that their place in the scheme of overall transportation will assume an ever increasing significance. As an example, the helicopter lines carried 228,000 passengers last year. Helicopter service provides the most practical approach to transfer between multiple airports serving one city, if the basis is time rather than economy.

We could expand this subject indefinitely, but representatives of the scheduled helicopter industries are obviously much more fitted to tell their story than we are.

Airport handling of limousines and taxi cabs is rather complex. In the case of franchised operators, a levy can be exacted on the basis of passengers carried. The current problem faced by many airports is an equitable means of handling taxi cab traffic. The AGTA, with justification, feels that competing forms of transportation should be subject to the same levies, which they must pay to support the operation of the airport. At many airports a charge is levied against taxi cabs for each pick up they make at the airport. This charge is either collected by a cab dispatcher or through some mechanical access gate. There are many inequities in this system. The charge is the same, irrespective of the number of passengers or length of the haul. Another widespread problem in the provision of taxi cab service is the fact that most airports are on an open rank status. This means that during periods of inclement weather, or during lull periods such as the midnight shift, taxi cab availability is limited. The franchised limousine operator, on the other hand, has the obligation of meeting all requirements, no matter what the volume, at any time of the day or night.

The day to day operation of airline ground transportation involves three agencies. These agencies are the operators, the airlines, and airport management. Through close liaison, the airlines and the ground transportation operators are making some closely knit efforts to meet the passenger demand generated by the move into the jet era. Liaison with airport management has been successful. The AGTA points out that as a transportation agency they have always been subject to regulation by State and local Public Utilities Commissions. During recent years, this position has changed as the right to enfranchise ground transportation operators has been given to airport management on an open bidding basis. The emphasis on occasion proved to be on unseen revenue rather than on demonstrated capability.

The result has been a lack of permanent certification for our established ground transportation operators, and a corresponding difficulty in securing the necessary capital to support a long-term investment in equipment.

Probably the single most perplexing problem is the one of multiple pick up and discharge points. When this industry was in its infancy, limousines were dispatched on a clear cut basis of one vehicle for each flight departure. In some localities, this is still the basis of operation. However, increasing volumes and efficient utilization of equipment have dictated a change in dispatching philosophy. Some major ground transportation operators now operate

their equipment on a headway schedule. This simply means that a bus will leave at certain stated time intervals, and the passenger load on this bus may include passengers from many different flights on many airlines.

As volumes have increased at our airports, congestion has been controlled by increasing decentralization of airline lobby facilities. The result is either loosely connected passenger lobbies or, in the case of many major terminals now being built, completely separate unit terminal facilities. This decentralization means that stops must be made to discharge passengers at many separate points. Obviously, these multiple stops add to the time our passengers must spend in city to airport transportation and added expense to the ground transportation operator. One operator states it this way—"We are at the sufferance of airport planners."

A similar problem exists in airport to city running time. A few weeks ago, I boarded a limousine in one of our cities. Running time to the downtown area was approximately 30 minutes. However, the pattern of one-way streets in the downtown area was such that my hotel was the last of approximately seven stops being made to discharge passengers. As a result, a little more than thirty additional minutes were spent in discharging all these passengers, making the total running time in excess of one hour. This experience has many parallels in cities across the country.

A composite effect of the many competitive aspects of the ground transportation problem has been in the declining percentage of increasing airline traffic being carried by the established operators.

As an example, some years ago United Air Lines operated a scheduled limousine service from Post and Powell Streets in San Francisco to the Airport. At that time, approximately thirty per cent of all passengers leaving San Francisco used this limousine service. In January of this year, scheduled limousine service began from the new downtown terminal just four blocks away. Approximately thirteen per cent of our boarding passengers have used this limousine service. This illustrates one of the major trends in the scheduling of ground transportation. As these major cities expand, and as air transportation is used by a wider segment of the population, our passengers are increasingly dispersed. This dispersal creates a complex scheduling problem for ground transportation operators, and the private automobile is taking an ever increasing amount of the business away from them.

Consider thirdly, our recommendation to the AGTA.

Last year, the airlines made a number of suggestions to the AGTA, outlining areas where we think improvement in procedures is needed. Our desire was to alert them to the greatly increased volume and peaking to be expected with the advent of Jets. We further recommend that Ground Transportation Operators sell tickets to passengers in advance of boarding. Collections are made before boarding, on the bus, and on the sidewalk at the destination. We suggested that the Industry embark on a program of advance fare collection by ticket.

Another area in question is baggage handling. We suggested that equipment wherever possible, should provide space for a certain amount of carry-on baggage, as well as better space for protecting luggage from damage. Additionally, baggage tags should be color coded by area to assist in handling after arrival at complicated unit terminals, where successive stops must be made to off-load passengers and baggage. At cities where downtown terminals provide full check-in, joint facilities to route baggage to the airplane should be developed. As an example, a conveyor belt some 200 feet long has

just been installed at SFO, accepting checked baggage at the sidewalk and conveying it to a staging area on the Ramp.

The airlines also touched on the necessity of providing clearly identified limousine dispatch points and improved information to the passengers. The major question any passenger has in using Ground Transportation is, "Where and when do I board the limousine to the destination I want?"

In considering the fourth question, "What has been accomplished?" we have asked some of the leading Ground Transportation Operators for their thoughts.

Mr. Moe Lerner, President of Airport Transport, Inc. of Washington, D. C. and Mr. Theodore E. Graff, President of Airlines Limousine, Inc. at Baltimore, Maryland, last month announced the purchase of a new fleet of luxury coaches.

We understand that—Carey Limousine Company of New York City is also planning the addition to their fleet of a substantial number of similar type coaches.

In addition, for local inter-terminal usage, they are planning the purchase of several Mercedes Benz busses with a capacity of thirty passengers. Their principal features provide for ease of walk on and off, plus plenty of space for rapid loading and unloading of baggage. There is also adequate space for carry-off baggage.

Mr. P. J. McNamee of Barrett Transportation, Inc., San Francisco, tells us the cashier system of selling tickets has been in effect now for a year and the result is a smooth orderly loading procedure.

Developments in this industry in the last 15 years have been startling. Last year, operating members of the Airline Ground Transportation Association had well over 1,500 vehicles in service, with gross revenues in excess of $30,000,000. The nine and twelve passenger stretch outs are being replaced with Flexible and GMC buses seating three to five times as many passengers as before. Pick up points have been centralized and combined in downtown areas, as an antidote to congestion delays. Downtown terminals, providing check-in and ticketing, have been built to accommodate our passengers. Running times have in turn been reduced as limited access highways were opened in many areas.

Running time, for example, is twenty-five minutes at San Francisco. It is also twenty-five minutes at Newark where the Westside Terminal was built with direct access to the tunnel and freeway to the airport. There will be a similar result for our O'Hare passengers in Chicago as soon as remaining segments of the Northwest Expressway are completed.

Consider fifth and last, if you will, the pattern for the future.

To the Customer's point of view, Ground Transportation is an all inclusive package, meaning transportation from the airport to centrally located areas in the city or his home. It includes not only the franchised operators of limousines and buses, but also the taxis, U-Drive cars, private automobiles, municipal bus services, even Helicopter service. Ultimately, the public will dictate the type and standard of service to be provided.

In addition to all these types of ground transportation, some possible approaches exist which have not yet been given a practical test. In general, these possibilities are tied in with a fixed and exclusive right of way. These rights of way can be broken down into subways, surface trains, or monorails. They all have one common, over-riding disadvantage. Development of the necessary capitalization has been almost impossible to achieve, since

tremendous sums cutting across City, airport and airline jurisdiction are involved. Ideally, this type of ground transportation would offer tremendous advantages, since traffic delays could be virtually eliminated. Additionally, we could handle check-in and ticketing en route because of the greater stability of this type of transportation. Monorail, particularly, captures the imagination, but a number of efforts to install such a system have run aground because of the capital requirements involved.* Lockheed Aircraft Corporation has recently announced plans to build a Monorail system to carry passengers to the Century 21 Exposition in Seattle in 1961. The system will operate one mile from downtown Seattle to the Exposition site. Cost is estimated at $5,000,000. There are other examples of Monorails such as the one you built right here in Texas. We understand there is some activity at Los Angeles in this field.

We believe that your major concern as you become involved in the planning and engineering of airports to service airline jet operations will be with the operation of our franchized ground transportation operators. Rental cars and private automobiles will naturally require extensive parking and access facilities, but these requirements can be anticipated rather accurately. Additionally, the revenue from these classes of ground transportation can be directly applied to the parking facilities provided to accommodate them.

We have spent a great deal of time here in outlining many of the problems jointly faced by the airlines, airport management, and the ground transportation operators in providing effective service for our passengers. There is no single industry-wide or Nation-wide answer to these problems.

What should our approach be? We believe that these scheduling and service problems vary so much from city to city that joint local action to develop the best possible service under local conditions has the best chance of success. Toward this end, the airlines and the Airline Ground Transportation Association have sponsored the organization of local ground transportation committees. Representatives of airlines, airport management and the operators meet at frequent intervals to discuss baggage handling procedures, schedule complaints, and anything which can be done to improve the pattern of service being provided.

There are other long-range measures which have a wider application. Discussion of these problems with your group illustrates one approach. We need a wider understanding, on the part of airport planners, of the place occupied by ground transportation in the total air transport picture. We must treat it not just as a revenue producing concession, but as a public convenience and necessity. Airport planning should include the fullest consideration for ingress and egress of all vehicular traffic, with separation of all classes of such traffic wherever possible. Planning should be coordinated with Municipal and State Highway groups.

Most of all, continuing attention must be given to the entire area of Ground Transportation, if this service is to keep pace with the advances being made in the air.

Finally, no discussion of Ground Transportation is complete without commending the operators for their fine Safety record. To be an integral part of airline service, the ground operators must promote the same feeling of confidence, know how, and service, that the airlines consider their major objective. This the ground operators are doing. We are pleased to see them plan for an even higher standard.

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*Aviation Daily—May 1, 1959.

Journal of the
AIR TRANSPORT DIVISION
Proceedings of the American Society of Civil Engineers

AUTO PARKING FOR EFFICIENCY AND REVENUE AT AIRPORTS

Ben E. Nunn[1]

Except in some of our most modern airports, the auto parking facility has not been given the consideration to which it is entitled. The tendency has been, and in many cases still is, to treat it as something quite unimportant. To do so is to overlook a substantial source of revenue and no Airport will ever become a good one without adequate, convenient and desirable auto parking facilities.

Airports are, by their very nature, places which draw private motor vehicles. We do not think of building airports in congested urban areas, because they need large open spaces that are not surrounded by high structures. To find ideal locations we must therefore go outside the thickly populated areas, and frequently we find ourselves away from surface transportation networks. The result is that a very high percentage of people visiting airports arrive in personal cars.

It is interesting to note that the ratio of automobiles to spectators and revenue passengers for a given airport remains at a fair constant.

For example, over a three-year period of operation the ratio of automobiles to spectators and revenue passengers remained at a constant of from 5 to 5-1/2 persons per car handled, at a given airport.

Thus it can be seen that if the number of revenue passengers plus spectators can be calculated the number of cars which can be expected can be fairly well evaluated. From this an individual airport survey of flight loads, etc., will give the approximate number of stalls necessary to handle the parking load.

Users of airport auto parking facilities are divided into two categories. One is that of the paid parking, and the other the airline employees and concessionaires who go to make up the permanent family at the airport. Of the two it is apparent that the major share of the revenue must be derived from the first group. The opinion is expressed that the paying public should be given every preference as to location, and other considerations that go to make up a desirable parking station.

Since we are concerned with revenue, we are interested in the net return as well as the gross. If our employees' parking area is so located as to be

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1. Secy. Treasurer, Parking Associates Enterprises, Los Angeles, Calif.

convenient to the public, the public will endeavor to use it, unless it is staffed at all times. This is costly, particularly when this staff will produce no revenue. Staffing is generally unnecessary, if in the planning stage, we arrange the employee's space so that it is not convenient to the public.

In planning the public parking area, a somewhat different approach is required. Here we want the most desirable location available. It should be as conveniently located as possible with consideration given to walking distances, areas through which people must pass after parking their cars, and accessibility from roadways.

It should not be forgotten that the parking public are the ones who bring the primary money to the Airport. Parking revenue is not all that should be considered. Other revenue is dependent upon the treatment received in the first instance. We in the parking business have learned from long experience that no one likes to walk over 600 feet to his final destination. With this in mind every effort should be made to put the parking customer in as desirable a position as possible.

One of the commonest errors in design today is to require the parker to pass in front of the terminal before being able to enter the parking facility. This error is often further compounded by forcing the parker to follow the same route on leaving. This type of planning at least doubles the traffic in front of the terminal. Most of the public have been to the airport before and prefer an adequate parking entrance in advance of the immediate terminal area. An exit equally free of terminal traffic is equally desirable.

Even though we are interested in revenue, we must bear in mind that there is a need for providing zones where passengers and baggage may be loaded or discharged without the necessity of paying a parking fee. This should be made possible without entering the parking premises.

The actual laying out of the Public Auto Parking is important. Angle parking is preferable, the degree of angle to be determined by the dimensions of the area. Traffic should be one-way, within the layout, and all turns should be clearly marked. The traffic pattern should be such that the customer following it will come to the exit without being confused. Signs are necessary, and they should be kept to a minimum. They should be legible, brief, and clear as to meaning, and placed at proper elevation. There should be no obstructions in the parking areas such as bumpers, curbs, etc.

Parking areas must be well lighted with floodlights placed so that dark spots are eliminated, this tends to prevent pilfering and accidents. Special care should be given to lighting of cross-walks and other hazardous points. Crosswalks should be flush with the parking area.

The auto park surface should be paved with a good grade of asphalt or macadam and well drained. Special consideration should be given to the problem of snow removal in areas where it may become necessary.

Aisles and stalls should be clearly outlined with traffic paint, and directional arrows should be painted on the surface at strategic points. Booths for attendants should be placed at entrances and exits, and they should be designed with consideration given to efficiency in operation, appearance, the comfort of employees, and speed of service.

Great care must be exercised in the selection of employees. Special consideration should be given to appearance, mannerisms, diplomacy and general ability to meet and handle the public. Attendants should be dressed in neat, attractive uniforms with identifying badges.

In the operation of an auto park, at any sizeable airport, thousands of dollars will be handled by your attendants each month. Every car entering a public parking area should be accounted for, and can be with positive controls. The new automatic devices being used many places have drawbacks with respect to control of overtime parking.

Although there is no way of determining the number of cars carrying passengers and those bringing sightseers, or others having business at the airport, we do know that sightseers and visitors are responsible for a sizeable portion of our parking business. This fact is apparent since the increased volume of parking on Sundays over week days is quite out of proportion to the difference in the number of air line passengers. Likewise unfavorable weather on a Sunday greatly affects parking revenue, although it may not affect the number of passengers flown into and out of the airport. Actually there is no exact yardstick by which the ratio as between the number of cars parked, and the number of passengers carried can be anticipated. The condition and situation of each airport is different, and the proper way to secure definite information is by careful survey at each airport.

I doubt if there is any department at any airport which will produce as high a return on the capital invested as will the Auto Park. When you realize that the parking facility is necessary for the growth of any airport, it seems only logical that it should be given full consideration.

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Journal of the
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THE FUTURE OF AIRLINE GROUND TRANSPORTATION

William J. Culbirth, Jr.[1]

Twenty-two metropolitan areas in North America presently develop in excess of 65% of the total dollar volume of domestic airline ground transportation. It is my understanding a very similar pattern exists in the airline passenger business. While there are more than 400 North American airports enjoying commercial, scheduled airline passenger service, the services and resultant problems we will discuss here today will be confined primarily to these twenty-two airports, proceeding on the axiom that today's problems at the large airports will be tomorrow's at the smaller ones.

Present airline ground transportation patterns are well known. In the large metropolitan areas motor coaches are utilized between the airport and downtown terminals. In the intermediate sized areas motor coaches and limousines are sometimes used in combinations. In certain instances, the converted sedan, known in the industry as "stretchouts", seating nine to twelve persons, are employed. In each instance the service is analysed and provided in accordance with the needs of the airline passenger and in conformance with the local regulatory system.

Our problems break down into three major categories:

1. Legal.
2. Operational.
3. Communications and mutual understanding.

Legal Problems

In California in 1953 the San Francisco International Airport entered into a contract, negotiated by open bidding, with a company never before in the passenger transportation business. The California Public Utility Commission granted a certificate of public convenience and necessity on the basis of a contractual arrangement between the airport and the company desiring to enter into the airline ground transportation business. This pattern has been repeated in other localities. The results, whether openly admitted or not, are as follows:

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1. Pres., Airline Ground Transportation Assn., New York, N. Y.

a. The paramount authority of the applicable public utility board has been abandoned to unqualified commissions and persons.
b. Airline ground transportation has been placed in a position of concession and not an integral cog of the North American travel industry predicated upon the theme of public service and subject to the scrutiny and regulatory processes of the proper authority. This means anyone with a desire and adequate finances can enter into a public utility without experience, trained personnel or know-how. What is worse, the person possessing this desire usually has an exaggerated idea of the value of the right to transport people between the downtown areas and airports and enters excessive bids. In the final analysis, it is you, the traveling public, who must pay these costs and herein you find one of the main causes of ground transportation being priced above similar types of services.
c. It is the public who suffers.

Operational Problems

Frequently the seat-in-car, or regular service, airline ground transportation operator does not operate the taxicab service at the airport. When this situation exists there is naturally somewhat of a competitive spirit existing between the two phases of services. In no way are these remarks meant to imply there is not a definite need of both types of services for exactly the opposite is true. The A.G.T.A. recognizes the need for both types of services and the passenger should be able to make his choice.

However, more and more airports throughout North America are giving way to pressure brought upon them and making the airport what we know as "open stand" pickup points. In simple language, this means any properly licensed vehicle can pick up fares at the airport. In doing this, two injustices are perpetrated on the air traveling public.

a. No one company is charged with providing adequate around-the-clock, 365 days a year service. The results are that during inclement weather conditions or hours of peak taxi usage at points other than the airport there are not adequate taxi services available.
b. To date, an economical, or equitable, means of collecting fees from taxicabs for the right to pick up passengers at an airport has not been devised. Some airports have installed a mechanical toll gate where a taxicab driver inserts a quarter to permit him to enter the loading zone. This quarter must be paid whether one person rides the cab or several. The same quarter applies whether you ride one mile or twenty. Other airports have no fee for taxicabs whatsoever. In any event, the airports using either of these methods establish unfair competition for the passenger patronizing the regular ground service and the ground service itself.

In examining these operational problems, it is easy for the most inexperienced layman to understand the inequities which exist in several localities today.

a. The contractual ground service must be geared to handle not only the peak hours of service during the day, but also stand ready to serve all passengers during inclement weather. This is uneconomical and unfair, particularly when inequities exist between competing forms of ground transportation.

b. Competing forms of ground transportation should have similar contractual specifications to insure the public of regulated, economical, adequate transportation, whether by taxicab or the regular ground transportation carrier.

Now let us look at the immediate future. Airline capacity for the transportation of passengers will increase about 40% in the next two to three years during the transition from the "piston" to the "jet" era.

It would seem to follow, if the airlines will do 40% more business, the ground operator can expect 40% more passengers. Our surveys don't bear out this prognostication. At the outset, the air travelers were pretty well destined to downtown area. As airline patronage increased, the ultimate destinations of passengers were dispersed over a wider and wider area. The tempo of this dispersal has stepped up considerably during the past two years. If airline ground transportation is to keep pace with the airlines, ways and means must be provided to take the passenger more places and as close to his ultimate destination as possible. To do this, the system must encompass a minimum number of stops and cover a wider area.

To this end experiments have been carried on these past three years with routes going into certain suburban areas. When proper planning and common sense has been applied these suburban routes have enjoyed some success. Therefore, it is safe to say the future ground transportation patterns will encompass a greater number of suburban routes.

Faster airplanes with greater carrying capacity will mean two things: (1) More travel will be confined to daylight hours. (2) There will be a greater concentration of airline departures during popular travel hours. In sitting with those of the various airlines responsible for the future scheduling of airplanes, we have been able to set up patterns, which will develop in the next 18 months, wherein 11 Boeing 707's or their counterparts, the DC-8, etc., are to depart from one airport within a half hour period. The airplanes have seating capacities, depending upon the configuration adopted, of from approximately 125 to 155 passengers. This means a potential of some 1,200 to 1,500 passengers, along with friends to see them off, will be making their way to this airport during the 1 to 1-1/2 hours prior to the scheduled departure. If 30% of these passengers were to use ground transportation, it would mean equipment would have to be available to accommodate, during a half hour period, of from 360 to 450 plus passengers. This will probably mean the following:

a. In areas served by jet aircraft more motor coaches of larger carrying capacities will come into use.
b. Coordinated schedules of ground equipment with specific flights will probably give way more and more to the 'headway' or scheduled ground service. Our surveys indicate passengers, when given the opportunity, disperse themselves voluntarily in accordance with their own likes and dislikes. Some people, by nature, like to allow themselves a great deal of time, others are last-minute arrivers, while most of us seek the road of moderation.
c. Concentrations of peak travel periods will mean greater investment for ground transportation equipment, the hiring of more personnel and even more skilled management and supervisory personnel. All this, plus improved communications, maintenance facilities and the other factors which go into the operation of automotive equipment, will mean

additional capital investments of major proportions. This single factor, more than any other, will discourage the average uninformed and untrained speculator who might believe the ground transportation business a fertile field. It will do much to keep the ground transportation business where it belongs; in the hands of companies and men experienced in transportation.

d. Larger fleets of equipment, used for fewer hours a day, will make it important for the ground transportation operator to diversify his operations, i.e., sight-seeing, etc., in a manner which will utilize his equipment and manpower during off-peak periods in order to continue to render an economical service.

e. Airport management will have to recognize that airline ground transportation is in every sense of the word a public utility and not just another concession to be grouped with the news stand, drug store and hot dog counter. Some common ground for sensible fees based on scientific formulae which enable the airport to have reasonable income, the public reasonably priced transportation, and the ground transportation operator a reasonable profit will have to be devised. Such formulae should encompass a mutual trust to permit the ground transportation operator a reasonable assurance, insolong as he renders a good service, his contract will be of a continuing nature. This will allow more orderly planning, the ability to attract qualified personnel and to make the necessary capital investments.

The ground transportation operator has had to face facts that have brought us to the following:

a. Helicopters as they are at the present and anything on the drawing boards, are too expensive to run and there are too many operational problems involved to seriously consider or contemplate the use of helicopters for the mass movement of passengers between downtown areas and the airport. Just attempt to consider the number of aircraft required, the flight patterns these aircraft would create and the expense involved, to name but a very few of the problems, to properly handle only 1,000 passengers during a peak hour, and you will start to see the reasoning behind this decision. Couple these with the cost of operation —somewhere between 20 to 30 times the seat cost per mile, depending upon the formula applied, as compared to the cost of a modern motor coach and you realize the economics involved.

b. Mono-rail is comparatively untried. Not being experts in mono-rail operations, we borrowed the best engineering brains available to us to determine the merits of this form of transportation for airport service. Their recommendations, in short, disclaim the practical application of mono-rail service for airport service under the proposals made to us. Thus, the A.G.T.A. has adopted a resolution against further consideration, at this time, of mono-rail airport service.

The standard complaint about ground transportation has been that as the aircraft became faster the ground service became slower. This is not borne out by the facts at the majority of major airports. Ground service speed has improved over the years, with air speed. The San Francisco service and Newark Airport are just two examples where turnpikes or freeways have reduced travel time by more than 30%. Thus, as we look forward to the future

we will find the limited access and thoroughway type of highway construction playing a major role in reducing airport ground transportation time.

We are presently working on automatic ticket vending machines which will be strategically located at terminal areas to speed up fare collections.

The A.G.T.A., in conjunction with the Air Traffic Association Committees on Ticketing and Baggage and Airport Terminal Services have been valiantly striving to improve baggage handling, loading facilities and general operating procedures.

Plans have been devised to not only inaugurate certain suburban motor coach services, to be able to more widely render ground transportation services, but we have gone further than this through the coordination of our services with rail and motor coach services already serving suburban areas.

New equipment has been designed, and is presently under construction, which will incorporate 6'6" high and 7' wide baggage loading access and egress with movable bulkheads which can accommodate quickly and adequately containerized or individual handbags and packages. These coaches incorporate more comfort for the passenger (air conditioning, improved seating, etc.) and other innovations I am not at liberty to speak about today.

We have gone to the field of electronics to improve our dispatching and equipment control through the use of two-way radio, teletype, autowriters and other up-to-date methods of communications. These are being tested now and put into use as rapidly as their tested reliability and applicability has been established.

It is our feeling airport to metropolitan transportation will long be served by surface vehicles and in most instances by motor coaches or their counterparts. We do not have all the answers. We have experience, ingenuity and intestinal fortitude, plus a great willingness to learn.

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AIRPORT REVENUE BOND FINANCING

Walter C. Cleave[1]

A copy of the National Airport Plan 1959 indicates over $1,285,000,000 as the estimated cost of required airport developments for the years 1959 to 1962.

Historically, just about every known method of raising money has been employed to meet airport costs. There have been federal and state grants where no repayment is required. General obligation bonds have been issued, which bonds are payable out of taxes levied against all taxable property in the municipality. Revenue bonds have been issued payable out of airport revenue available after payment of operating and maintenance expenses. In this category, we find Port of New York Authority, Chicago O'Hare Airport, Denver, Kansas City, Tulsa, Detroit-Wayne, Flint, Dallas, Boston, Atlanta, and others.

Today municipalities have a pressing need for airport improvements which will cost hundreds of millions of dollars. Most of them, however, have an even more pressing need for streets, schools, sewers, water systems, libraries, hospitals, and other essential municipal facilities. In some cases there is not enough margin within the limits of their general obligation debt to go around. A substantial portion of the needed airport improvements will not be made unless they can be financed outside the debt limit with some type of revenue bond issue.

Most public bodies that are likely to consider revenue bond financing already have one or more airports in operation. All existing commitments must be studied and worked into any proposed program. All commitments must be protected. If any prior commitments present serious problems to financing an additional airport, renegotiation may provide a solution.

In considering airport financing, it is my recommendation that the public officials who face the problem work with recognized airport consultants, competent bond attorneys and investment bankers that can demonstrate a good record of revenue bond financing. Such a team can usually solve any financing problem.

Extreme care should be used in planning and developing the financing in order to interest investors in airport revenue bonds. The investor has many opportunities to put his dollars to work, so if you want some of these dollars,

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1. Vice Pres., Blyth & Company, Chicago, Ill.

offer the investor a sound bond issue. That you are in real competition for the investor's dollar can best be understood when we realize that revenue bond issues marketed in 1958 totalled $1,772,000,000 and 1959 may equal or exceed that total.

Care should be used in planning each bond issue so that future needs can be provided.

There is no point in devoting any of the few minutes allotted to me to the discussion of federal or state grants, or tax supported bonds. I feel that the time has arrived to reconsider the security pledged to the payment of interest and principal of airport revenue bonds if we wish to develop a broad market and place these bonds in an investment category that will provide money at reasonable interest rates.

Relatively few airports have been financed through the issuance of revenue bonds. Moody's Municipal and Government Manual 1959 lists the following as having issued airport revenue bonds:

Airport

Interstate Agencies
- Port of New York Authority

Alaska
- Juneau

Arizona
- Phoenix

Arkansas
- Little Rock

California
- Ontario

Colorado
- Denver

Florida
- Dade County
- Hillsborough County Aviation Authority
- Orlando
- Sarasota & Manatee Cos.

Georgia
- Atlanta

Michigan
- Flint
- Pontiac
- Wayne County

Minnesota
- New Ulm

Missouri
- Kansas City

Nebraska
- Columbus

North Carolina
- Durham
- Forsyth County

Ohio
- Toledo
- Youngstown

Texas
- Dallas
- Greenville
- Midland
- Rockwall
- San Antonio

Wisconsin
- Madison

Wyoming
- Natrona County

In addition to the above should be added Chicago and Tulsa.

The brief history of airport revenue bonds demonstrates that a new concept of airport revenue bond security is needed; a concept that is not new in

revenue bond history. Airport revenue bonds issued in the future should be set up so that the interest and principal are paid as a first charge against all airport revenue.

The rapid growth of commercial aviation and the continuous technological advances in the air transport industry have required and will continue to require the expenditure of tremendous sums of money for expanded airport facilities. If we are to avoid high interest rates for the borrowed portion of this money, the gross revenue bond concept is, in my opinion, a justifiable way to do it. The more favorable the bondholders position in relation to other claims on airport revenues, the cheaper he will put his money to work.

This concept of a gross revenue bond seems further justified when we consider that commercial aviation transporting people, mail, express and freight is rendering a community service. Commercial aviation also renders an economic service in that it provides employment for local citizens and requires the goods and services of local businesses in every area it serves. For this community and economic service, the community should be willing to make such contribution as may be needed to help operate and maintain its airports. If such a community contribution is needed, it should be provided out of general funds. To accomplish the gross revenue bond concept, it may be necessary to amend existing airport revenue bond enabling legislation.

Wayne County, Michigan and Flint, Michigan will advance general fund moneys to pay interest and principal of airport revenue bonds in the event airport revenues are insufficient for such purposes.

The City of Dallas is an interesting example. Its Airport Revenue Bond Ordinance provides that the City will provide money in its annual budget from its General Fund Revenues and to pay as administrative expenses of the City, the administrative expenses of its Department of Aviation.

So as to avoid competition among airports in a community, the city or other public body issuing airport revenue bonds should combine its airports into a single airport system, operate them as a unit, and have one revenue bond issue to meet the capital costs of any or all airports in its system. Revenues from all the airports should be deposited into a single airport revenue fund which supports the revenue bond issue. Once again, amending legislation may be necessary to accomplish this. The Port of New York Authority operates its airports as a system and recently a bill was introduced in the California Legislature proposing the creation of a Golden Gate Authority to take over toll bridges, airports, and certain port facilities in the San Francisco Bay area.

A city or other public body should be authorized to provide in its bond ordinance any order of priority for the use of moneys deposited in the airport revenue fund. It is my opinion that this order of priority is of extreme importance and I again recommend that airport revenue bonds be payable both as to interest and principal as a first charge against the gross revenues of the airport system. An ordinance should provide that after the revenue bond interest and principal has been paid, moneys remaining in the revenue fund could be used for a debt service reserve, for operating and maintenance costs and for any other purposes the issuing body deems necessary. We feel that such provisions would make airport revenue bonds readily marketable at a reasonable interest rate.

A revenue bondholder usually has only the project revenues available to pay his interest and repay his principal. This emphasizes the fact that great care must be used to develop a plan that will be revenue producing as long as the bonds are outstanding. If a program is loosely drawn and does not provide an

assured continuity of revenue, it may prove difficult, if not impossible, to sell the bonds. Such a project would never get past the drawing board.

To get a little more specific, not too many years ago a great future was predicted for Carter Field. Now, Love Field has the volume of traffic. If revenue bonds had been issued to finance Carter Field, the bondholder probably would be very unhappy with his investment if he counted on the business now going into Love Field.

Willow Run is another example of a large airport which seems doomed to lose its commercial flights to some other airport facility. Some lines have already transferred to Detroit Metropolitan Airport and we are informed that all commercial airlines will move from Willow Run to Detroit Metropolitan Airport very soon. Detroit is planning about a $15,000,000 revenue bond issue to provide facilities at Detroit Metropolitan Airport to handle this business. Needless to say, if revenue bonds had been issued for Willow Run, the bondholders would have a bond of doubtful value when this transfer is completed.

Chicago just financed O'Hare Field by a revenue bond issue. These bonds should prove sound because of the kind of contracts signed by the airlines. Chicago still operates Midway, frequently reported to be the busiest airport in the world. The ink on the O'Hare bonds is hardly dry before the General Assembly of the State of Illinois is asked to authorize a study commission to study a new major airport suggested for south Cook County.

The National Airport Plan 1959 proposes new airports at Los Angeles; Washington, D. C.; Jacksonville, Florida; Baltimore, Maryland; Grand Rapids, Michigan; Houston, Texas; Tacoma, Washington and many others. How will they be financed? Where and how will they fit into each community's airport program? If they are to be financed by revenue bonds, each bond issue should embody the principles outlined to you today.

You gentlemen know better than I of the many advances that appear possible. Extreme care must be used if revenue bond financing is contemplated or the money needed may not be forthcoming to meet the costs of necessary new or expanded airport facilities.

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RUNWAY LENGTHS FOR JET TRANSPORTS

Robert Horonjeff[1] and Richard Coykendall[2]

INTRODUCTION

We have been asked to discuss runway lengths for jet transports. Runway length is much talked about these days, and most everyone associated with airport development is naturally concerned about it. In considering our assignment, we were of the opinion that the civil engineer would be interested in the various factors which can influence runway length.

A detailed presentation of all these factors is beyond the scope of this paper. Consequently, we have attempted to simplify our presentation by generalizing certain conditions and omitting a large amount of detail which would not be of interest to the civil engineer. Thanks are extended to the Boeing Airplane Company, Douglas Aircraft Company, Lockheed Aircraft Corporation, and Convair Division, General Dynamics Corporation for furnishing the performance data which made this presentation possible. Thanks are also extended to Mr. Gale Ahlborn of the Institute of Transportation and Traffic Engineering, University of California, to Mr. Kirke Comstock of United Air Lines, and to Mr. Roy Simpson of Pan American World Airways for their suggestions in preparing this paper.

We have grouped the factors which have a bearing upon runway length into three general categories as follows:

1. Performance requirements imposed by the government on aircraft manufacturers and operators.
2. Environment at the airport.
3. Those factors which establish the operating take-off and landing gross weights for each aircraft type.

1. Prof. of Transportation Eng. and Research Engr., Institute of Transportation and Traffic Eng., Univ. of California, Berkeley, Calif.
2. Aeronautical Engineer, Flight Engineering Division, United Air Lines, Inc., San Francisco, California.

AT 3

Performance Requirements Imposed by the Government

Transport category aircraft are licensed and operated under a code known as the "Civil Air Regulations". This code is promulgated by the Federal Government in coordination with industry. The regulations govern the aircraft gross weights at take-off and landing by specifying performance requirements which must be met in terms related to the runway lengths available.

The regulations pertaining to piston-engine aircraft consider two general cases in establishing the lengths of a runway necessary for safe operation of aircraft. They are:

Take-off involving an engine failure, wherein sufficient runway is required to allow aircraft to continue the take-off despite the loss of power, or else brake to a stop.

Landing, wherein sufficient runway is required to allow for normal variation in landing technique, overshoots, poor approaches, and the like.

The new regulations pertaining to turbine-powered transports retain in principle the above two criteria, but a third criterion has been added which is referred to as the case of

All-engine take-off, wherein sufficient runway is required to allow for likely variation in lift-off techniques and for the distinctive performance characteristics of this new family of aircraft. This particular regulation is aimed toward the everyday, normal take-off maneuver since engine failure occurs rather infrequently.

The length needed at an airport by a particular type and weight of turbine-powered aircraft is established by one of the foregoing three cases, whichever yields the longest length.

In the regulation for both piston engine aircraft and turbine powered aircraft the word runway refers to full strength pavement. Thus in the discussion which follows, the terms "runway" and "full-strength pavement" are synonymous. In discussing the effect of the regulations on length of runway, however, it is important to note that the current regulations for turbine powered aircraft do not require a runway for the entire take-off distance while the regulations for piston engine aircraft normally do.

To indicate why there is a difference in the two regulations with regard to the length of full-strength pavement (runway) we shall examine in more detail the new regulation pertaining to turbine powered transports.

The three cases referred to above as defined by the current turbine-powered transport regulations (SR-422A) and the proposed revision (SR-422B) are illustrated in Fig. 1.

The landing case (Fig. 1a) is probably easiest to explain. The regulations state that the "landing distance" needed for each aircraft using the airport must be long enough to permit the aircraft to come to a full stop with 60 per cent of this distance, assuming that the pilot makes an approach at the proper speed and crosses the threshold of the runway at a height of 50 ft. The "landing distance" must be of full-strength pavement. The landing distance for piston engine aircraft is defined in exactly the same manner.

The normal, or "all-engine take-off" case (Fig. 1c) defines a "take-off distance" which, for a specific weight of aircraft, must be 115 per cent of the actual distance the aircraft uses to reach a height of 35 ft. Not all of this distance has to be of full-strength pavement, however, because pilot technique would never vary so greatly as to need all of it before lifting off the ground.

"Take-off distance" (115% of distance to 35 feet)
115% of lift-off distance
Lift-off distance
Distance to 35 feet
Engine failure at V1
"Accelerate-stop distance"
Decelerate to stop
Runway
Stopway
Take-off run
Clearway cannot be more than half this distance
"Clearway"
35ft
NORMAL TAKE-OFF CASE
(c)
ENGINE FAILURE CASE
(b)
Stopway - At least as wide as runway; Must support airplane without damage in aborted take-off.
Clearway - Minimum 600ft wide: No higher than end of runway, clear of fixed obstacles, and under airport control
"Landing distance"
50ft
Distance to stop must be 60% of landing distance
Stop point
LANDING CASE
(a)
• See text

Fig. 1 — Summary of turbine-powered aircraft performance regulations affecting runway length requirements.

What is necessary is that all this distance be free from obstructions to protect against an overshooting take-off. Consequently the regulations permit the use of a "clearway" for part of this distance. A "clearway" is defined as "an area beyond the runway not less than 300 ft. on either side of the extended centerline of the runway at an elevation no higher than the elevation at the end of the runway, clear of all fixed obstacles, and under the control of the airport authority". Up to one-half the distance between (a) 115% of the distance to reach the point of lift-off and (b) the "take-off distance", may be "clearway". The remainder of the "take-off distance" must be full-strength pavement and is identified as the "take-off run".

For the engine-failure case (Fig. 1b), the regulation specifies that the "take-off distance" required is the actual distance to reach a height of 35 ft with no percentage applied as in the all-engine take-off case. This recognizes the infrequency of this occurrence. The regulations again permit the use of a "clearway", in this case up to one-half the difference between the distance to lift-off and the "take-off distance", the remainder being full-strength pavement. The regulations for piston-engine aircraft normally required full strength pavement for the entire take-off distance.

As mentioned previously, the engine-failure case requires that sufficient distance must also be available to stop the airplane rather than continue the take-off. This distance is referred to as the "accelerate-stop distance". For piston-engine aircraft only full-strength pavement was normally used for this purpose. The new regulation, however, recognizes that an aborted take-off is relatively rare and permits use of lesser strength pavement, known as a "stopway", for that part of the accelerate-stop distance, beyond the "take-off run". The "stopway" is defined as "a rectangular area beyond the regular runway, centrally located about the extended centerline of the runway, not less in width than the width of the runway and designated by the airport authorities for use in an aborted take-off, such area being capable of supporting the airplane when so used without inducing structural damage to the airplane."

It is apparent that both the "take-off distance" and "accelerate-stop distance" will depend on the speed the aircraft has achieved when an engine fails. The speed at which engine failure is assumed to occur is selected by the aircraft manufacturer and is referred to as the "critical engine failure speed, V_1".* If an engine actually fails prior to this selected speed the pilot brakes to a stop. If an engine fails at a speed greater than V_1 the pilot has no other choice but to continue the take-off.

Since, for piston-engine aircraft, full-strength pavement was normally used for the entire "accelerate-stop distance" and the "take-off distance", it was the general practice to select V_1 so that the distance required to stop from the point where V_1 was reached was equal to the distance (from the same point) to reach a specified height above the runway.** The runway length established on this basis is referred to as the "balanced field concept" or "balanced runway" and results in the shortest runway. For turbine powered aircraft the selection of V_1 on this basis will not necessarily result in the shortest runway if a clearway or a stopway is provided.

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*The regulations for both piston and turbine aircraft specify that V_1 cannot be so high that the aircraft begins to fly, yet it must be high enough so that it will respond to aerodynamic control from the rudder and ailerons.

**For piston-engine aircraft, the height is not fixed at 35 ft.

For this reason it is necessary to understand the interrelationships between V_1 and the various components of the "take-off distance" and the "accelerate-stop distance". These are illustrated on Fig. 2. At increasingly higher V_1 speeds, the "take-off distance" becomes shorter and shorter, because the aircraft has the benefit of all-engine acceleration for greater portions of the take-off roll, but the "accelerate-stop distance" is correspondingly increased.

Although Fig. 2 was primarily to illustrate the clearway and stopway concepts, the "balanced field concept" is also shown for comparison and corresponds to the cross-over of the take-off and stopping requirements.

When "clearways" and "stopways" are utilized several alternatives are possible as follows: (Refer to Fig. 2)

1. If the same V_1 is selected as in the "balanced-field concept" the lengths of the "clearway" and "stopway" are equal. This would mean that the full-strength runway (indicated as L_{U-1} on Fig. 2) could be shortened a distance equal to the "clearway", but a "stopway" would have to be constructed.
2. Another alternative is to select V_1 so as to balance the "accelerate-stop distance" with the "take-off run". In this case the runway becomes L_{U-2} (Fig. 2) which is less than L_B and no "stopway" is required. Thus the runway has been shortened.
3. Another alternative is to select a fairly high V_1 in order to reduce the "take-off distance", but when this is done the accelerate-stop distance is increased greatly. For this case the length of the runway is indicated as L_{U-3} (on Fig. 2), but note what happens to the "accelerate-stop" distance. This alternative may be advantageous to the operator at airports where there are obstacles near the ends of the runway.

Thus one can see that the new regulations offer a number of alternatives to the aircraft operator. It should be emphasized that the "take-off distance" and the "take-off run" for the engine-failure case must be compared with the corresponding distances for the normal all-engine take-off case. The longer distance always governs.

From the presentation thus far it is apparent that the length of the runway is intimately associated with the heights, speeds, and other requirements specified in the performance regulations. Since the issuance of the initial regulation pertaining to jet transports, there has been one modification and another is about to be adopted. Each of these has had an effect on runway length.

While we do not profess to consider all aspects of the problem, it is our opinion that both aircraft operators and airport management will ultimately utilize "clearways", because clearways will, for a fixed available length of runway, allow the operator additional gross take-off weight with less expense to airport management than building full-strength pavement.

Airport Environment

Thus far we have shown how the requirements imposed by the government can influence runway length. Certain conditions at the airport can also do so. The more important of these conditions are (1) temperature, (2) surface winds, (3) gradient of the runway, and (4) elevation of the airport.

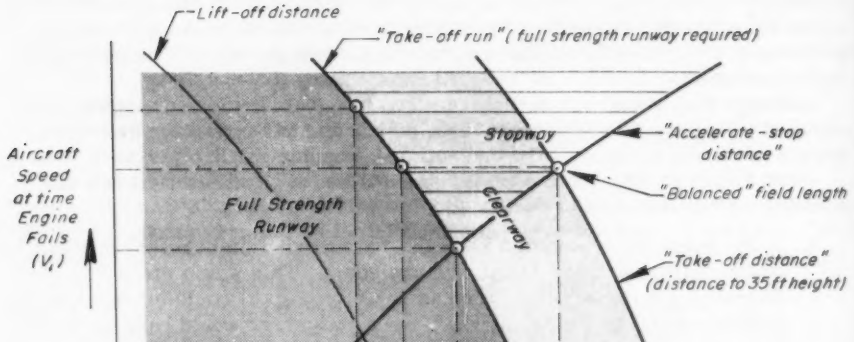

Fig. 2 — Turbine-powered aircraft take-off requirements, engine failure case.

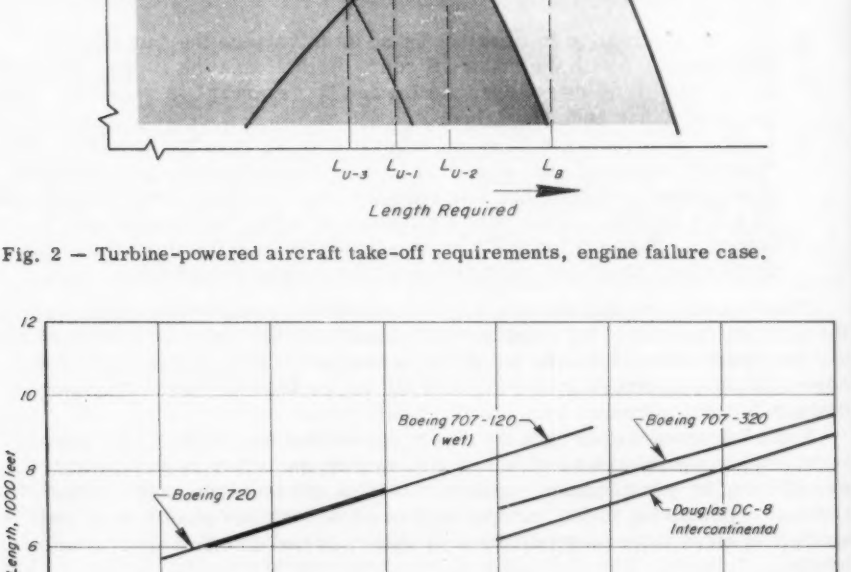
Runway Length, 1000 feet
Trip Length, nautical miles
Boeing 707-120 (wet)
Boeing 707-320
Boeing 720
Douglas DC-8 Intercontinental
Lockheed Electra (wet)
Assumptions:
Enroute - No wind, standard temperature, cruise conditions as in text.
Airport - Sea level, no wind, standard temperature, no runway slope

Fig. 3 — Basic runway lengths for typical jet transports.

For purposes of determining relative effects of variations in these conditions, each condition was broken down into components that could be numerically expressed. For each aircraft included in this analysis the runway lengths for several trip lengths were computed from performance data furnished by the manufacturer and for the following assumed condition components at the airport and enroute:

1. Airport is at sea level.
2. Temperature at the airport is standard (59° F).
3. Runway is level in a longitudinal direction.
4. There is no wind blowing on the runway.
5. There is no wind blowing enroute to destination.
6. The temperature is standard enroute.
7. Aircraft is loaded to capacity with passengers and cargo.
8. Aircraft is cruised at speeds shown in Table 1.

The lengths so obtained were designated as "basic runway lengths" and are shown on Fig. 3. Next, each of the components at the airport was varied, one at a time, while the remaining seven were kept constant. The runway lengths (corresponding to the trip lengths for which the basic lengths were computed) were computed and expressed as a percentage of the basic runway lengths. In this manner the relative magnitude of each of the airport conditions was obtained. The results of this analysis are presented graphically in Fig. 4.

The turbine-powered aircraft included in this analysis are shown in Table 1. The table also shows the range in trip lengths for which the computations were made, the manner of cruise, and the government regulation on which the runway length was based. We should like to emphasize that the lowest and highest trip length indicated in the table does not necessarily mean that these are absolute limits of range within which the aircraft can be operated economically. These numbers were selected for the purpose of the analysis only, although in our opinion they are representative. On the charts we have chosen the terms "shorter trip length" and "longer trip length" to express distances which approach the smaller or the larger of the lengths shown in the table.

TABLE 1 — AIRCRAFT AND TRIP LENGTHS

Aircraft	Range of trip lengths[1]	Cruise conditions	Govt. regulations to establish runway length
Douglas DC-8	2000-3500	Mach 0.81 @ 30,000 ft.	SR-422B[3]
Boeing 707-320	2000-3500	Mach 0.81 @ 30,000 ft.	SR-422B[3]
Boeing 707-120	700-2100	Mach 0.82 @ 30,000 ft.	SR-422[2]
Boeing 720	500-1500	Mach 0.84 @ 30,000 ft.	SR-422B[3]
Convair 600	700-2100	Mach 0.84 @ 35,000 ft.	SR-422B[3]
Lockheed Electra 188	300-1500	Max. Cruise Power @ 20,000 ft.	SR-422 [3,4]

[1]Trip lengths expressed in nautical miles (1 n. m. = 1.15 statute miles)
[2]Runway lengths obtained from FAA approved flight manuals.
[3]Runway lengths are based on estimated performance (without clearway).
[4]Runway lengths are based on estimated performance with water alcohol injection

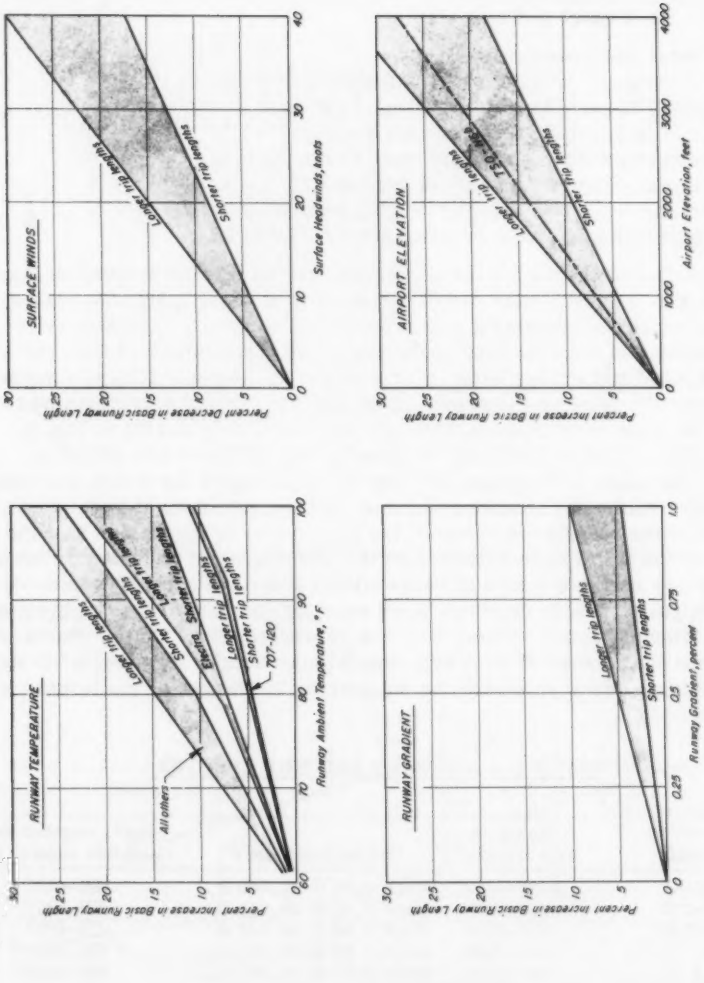

Fig. 4 — Effect of airport environment on runway length.

In Fig. 4, envelopes have been drawn incorporating the effects of all the aircraft included in Table 1. These envelopes labeled "longer trip lengths" and "shorter trip lengths" have been drawn as straight lines. This does not mean that each individual aircraft behaves precisely as indicated by the envelopes. The influence of each individual aircraft was omitted in order to simplify the illustration.

An examination of Fig. 4 reveals that, in general, the effect of airport conditions on runway length is dependent on the length of trip; the larger the airport condition the greater is the spread between the shorter and longer trip lengths. This is to be expected since the longer trips require more fuel and hence the aircraft are heavier at take-off.

Of interest in Fig. 4 is the wide variation in the effect of temperature. On a hot day (100° F) the increase in runway length (over the basic) varies from 11 per cent to 29 per cent.* For this reason, a too rigid standardization, in planning guides, of the effect of airport temperature for the purpose of establishing runway length may not be desirable.

The wide variation in the effect of airport elevation is also shown on Fig. 4. The requirements of FAA Technical Standard Order N6b have been superimposed on the figure in order to illustrate how the individual aircraft compare with this requirement.

Conditions Which Establish the Operating Take-Off and Landing Weights

Let us now consider the factors which build-up the weight of the aircraft at take-off, weight being a dominant factor in the determination of runway length. The weight of aircraft at take-off (assuming 100 per cent payload) depends mainly on (1) length of trip, (2) the conditions to be encountered by the aircraft enroute, and (3) the speed and altitude at which the aircraft is flown.

The enroute conditions which were considered in our analysis are (1) winds aloft and (2) temperature aloft. A strong headwind means more fuel since it reduces the ground speed of the aircraft and requires that it remain aloft a longer time than if the winds were not present. For the same reason a strong tail wind is quite beneficial insofar as take-off weight is concerned.

The result of our analysis is shown on Figs. 3 and 5. The same procedure was used for the analysis as described for the airport conditions—that is to say, one condition component was varied while the remaining seven were kept constant. The "basic runway lengths" referred to in the charts are the same as shown in Fig. 3. Fig. 3 also shows the effect of trip length on runway length. The same procedure was used to plot the data on Fig. 5 as was described for the airport conditions. For example, the winds aloft were varied while the remaining seven factors were kept constant.

Turning to Fig. 5 it will be noted that there is a wide variation in the effect of enroute winds from shorter to longer trip lengths. This can be explained by the fact that a headwind on very short trip lengths increases the time aloft much less than a headwind on long trip lengths.

The effects of enroute temperature on runway length requirements are small as shown in Fig. 5. This can be explained by the fact that although at higher temperatures there is usually some reduction in engine efficiency, this

*If the computations were made on the basis of a dry turbo-prop engine the variation at 100° F would be from 11% to 44%.

Fig. 5 – The effects of enroute conditions and trip length on runway length.

reduction is generally offset by the corresponding decrease in air density which reduces the drag.

The effect of speed of aircraft enroute in shown in Fig. 5. To obtain these charts the take-off weights and runway lengths corresponding to the highest practicable operating speed were calculated from the performance data furnished by the manufacturers. The computed lengths were then expressed as a percentage of the "basic length" shown on Fig. 3. It should be pointed out that these high speeds, although possible, are not likely to be utilized by the aircraft operators because of large penalties in fuel consumption and maintenance costs. The effect of speed increases as the length of trip increases, which is to be expected, and it will be noted that the percentages can become appreciable.

CONCLUDING REMARKS

We have tried to demonstrate that runway lengths for a specific model of aircraft can vary widely, depending on the length of trip and the environmental conditions at the airport and enroute.

In our opinion the establishment of runway length has reached a state of sophistication such that it is no longer sound to establish runway lengths solely on the basis of numbers listed in planning guides. The intent of these guides is to provide a starting point for more detailed studies, but they are too often used for construction purposes.

We believe that the proper way to establish runway lengths at an air carrier airport is for the airport planner to work closely with the aircraft operators, examine the route structure, the equipment to be used, the environmental conditions, and the carriers' estimates of runway lengths. In performing this task the airport designer will need to have the necessary background to carry out his assignment intelligently.

Finally, if the civil engineer is to play a dominant role in airport planning, he must acquaint himself with the operating characteristics of the vehicles and the performance regulations under which they must operate. We hope this paper will be of aid in this direction.

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PARIS-ORLY AIRPORT AND ITS NEW TERMINAL AREA

Henri Vicariot[1]

SUMMARY

The development of the Master Plan for Orly Airport is reviewed in detail. The new terminal building under construction is a major feature of the article.

The Orly Airport which is, with Le Bourget Airport, the main airport of the "Paris Airport Authority", is presently undergoing its most important construction phase. The projects presently under construction have been the subject of very long studies, which started at the end of the second World War. The construction is planned in successive phases, the most important being the one presently under progress, which is due to be completed in 1960 with the opening of the final Terminal installations.

The following document is divided into three chapters:

Master plan data
Terminal installations
Jet Age problems

Master Plan Data

We shall examine successively runways, taxiways, central area, road traffic, industrial areas and transportation means used for the connection of the Paris Airport with the City.

Runways

The first master plan drawn up in 1946 was a tangential plan similar to the one which was under study for Idlewild.

As of 1947, the Paris Airport gave up this planning which seemed to be unsatisfactory for the traffic expected for Paris: (there were too many runways going in too many directions). Considering the allowable crossing winds

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AT 3

of modern planes, and the dissymmetry of the wind conditions found at Orly Airport, such a complex and expensive "all directions" runway network was not required.

The evolution of the master plan has confirmed this point of view. At Idlewild the tangential plan, as it was originally drawn up, has also been abandoned. For the time being, only the large central area, provided in the original plan, remains. It is surrounded by two taxiways and a parallel runway network going in the two main directions.

As of 1947, the Paris Airport had drawn up a plan for parallel runways, similar to the plan which was prepared for the London Airport. The plan concerned had three directions for the runways, the distance between two parallel runways being approximately one mile. However, in the main East-West direction, a third runway, had been added. In 1950, due to a better knowledge of the meteorological conditions over Orly and of the allowable cross winds for the planes, which were always getting heavier, it has been possible to suppress the third set of runways which were not yet executed. The master plan presently shows three parallel runways, two of them being staggered parallel type, and two parallel runways, in the secondary direction. A third runway is to be found in this direction. This runway has been constructed during the war, its strength is very poor and it is seldom used. Fig. 1.

At the present time, only two runways have been constructed: a main East-West runway and a North-East/South-West one. They are equipped for instrument flights with an approach light system and I.L.S. and G.C.A. system. Consequently it is still possible to review and modify the Orly master plan and to adapt it to the actual conditions of the future traffic.

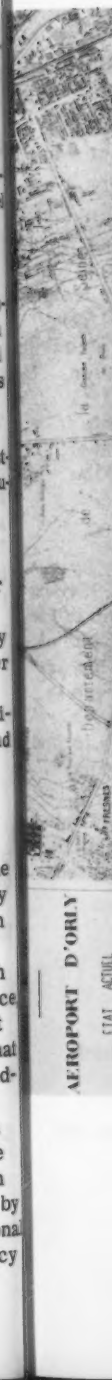
In what direction will this plan evolve? Two projects are presently under study.

The first is to suppress one of the three East-West runways and keep only a two staggered parallel runway system, one for landing operations, the other for take-off operations.

These two runways constitute the main element of the airport. Their utilization coefficient is equal to 97% with a cross wind of 21 feet per second, and increases to 100% with a cross wind of 40 feet per second. The use of the runways in the East-West direction, with a west wind would be adequate in two-thirds of the cases. The distance between the axial line of the two runways would be 4,000 feet. The capacity of such a system, according to the conclusion mentioned in the Curtis Report, could reach 100 movements in the peak hour. According to our estimates, this traffic corresponds to an hourly peak of 3,000 passengers and to an annual amount of approximately 8 million passengers.

Under these conditions, the third East-West runway planned for the North area of Orly would be of no use. We plan to execute it only as a last resource should our forecasts be found too low in the far future. It is to be noted that a small town is located 1/2 mile from the Western end of this runway and that difficulties which could be encountered give us an additional reason for avoiding its construction.

The second is to study the elimination of the second runway oriented in a North-East/South-West direction or at least postpone its construction to the last. The main direction having an utilization coefficient equal to 100% with a cross wind of 40 feet per second, the second direction would only be used by airplanes of old types or for airplanes in trouble; that is to say for exceptional cases. Under these conditions, only one runway, considered as an emergency runway would be sufficient in this direction. However, it is not certain.



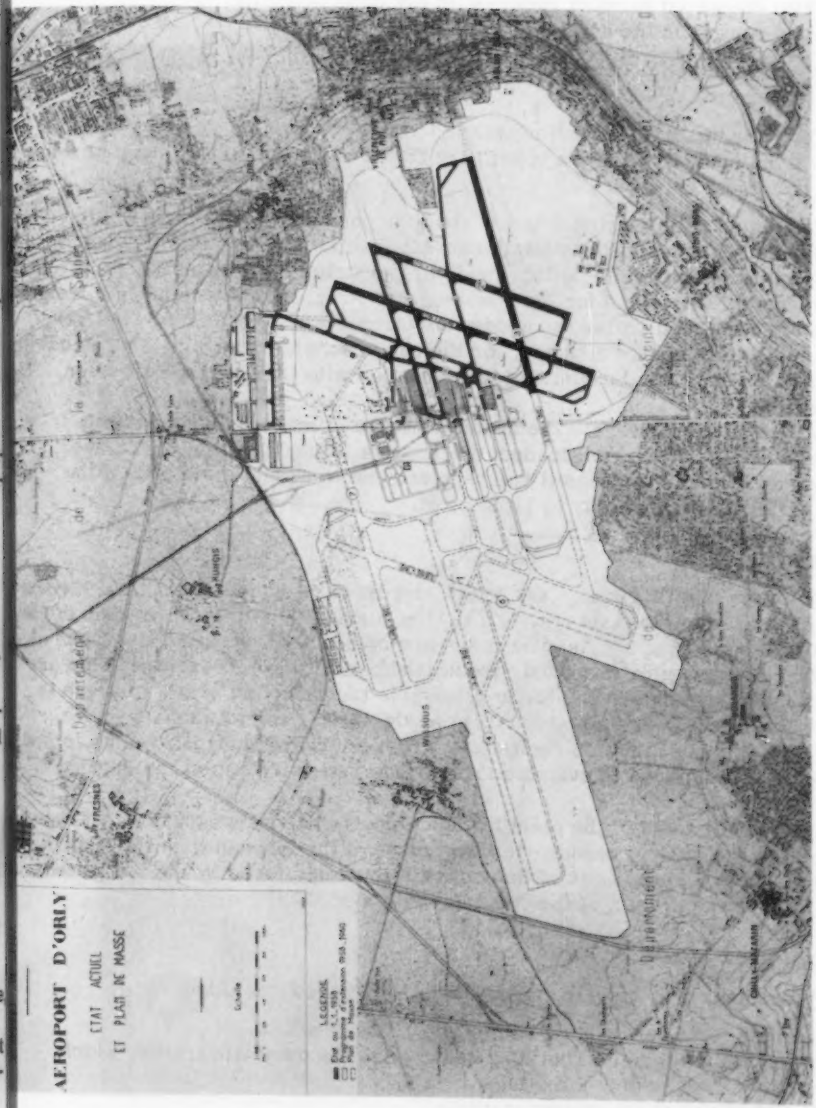


Fig. 1

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Summarizing, the Orly master plan would only include in the future, three runways, i.e.:

- two staggered parallel runways, in the main direction,
- one runway in the secondary direction.

In our opinion a double interest exists in simplifying the runway system, that is to say:

- to save important investments
- to maintain large areas permitting the construction of commercial and industrial facilities.

The future of an airport depends upon the possibilities it offers for the development of the airport installations. All specialists know the importance of the requirements pertaining to: single or multiple terminal installations and large car parking areas for the "passengers" area, simple or multiple freight stations, docks and stores for goods (the forecasts in this field are yet very dubious), large industrial areas, for the construction of hangars, shops and installation of various industries in connection with the air transportation system.

Length of the runways: The altitude and the climate of Paris permits take-off of four engine jets, full loaded, on runways, 10,000 feet long. However, for various special reasons it has been decided to extend the length of the Orly I.F.R. landing runway to 11,000 feet.

Taxiways

From the very beginning, the Paris Airport has adopted an original method for the survey of the taxiways. We have assumed a simulated operation of the airport, considering all the wind cases and using the large transport types of airplanes, existing or proposed, whose landing and take-off requirements are known. We have then been able to determine the exit point of the runways in the different cases and also to determine the taxiing run of airplanes with their respective utilization coefficient. These surveys have allowed us to find the shortest ways and to evaluate the average estimated run of the taxiing airplanes.

A survey of some of the main foreign airports has shown that the average estimated run of Orly was shorter than those of the largest airports studied in this survey. This is one of the main advantages offered by the staggered parallel runway system of the two main runways.

Central Area

The central area of Orly airport (Fig. 2) includes the following:

- a main terminal building with piers (or fingers),
- eventually a terminal building assigned to the domestic traffic, which will be constructed in the future,
- one or several air freight stations,
- Airport administrative and technical offices—Government agencies and airlines offices,
- fuel supply installations,
- heating and power station,
- two service stations,

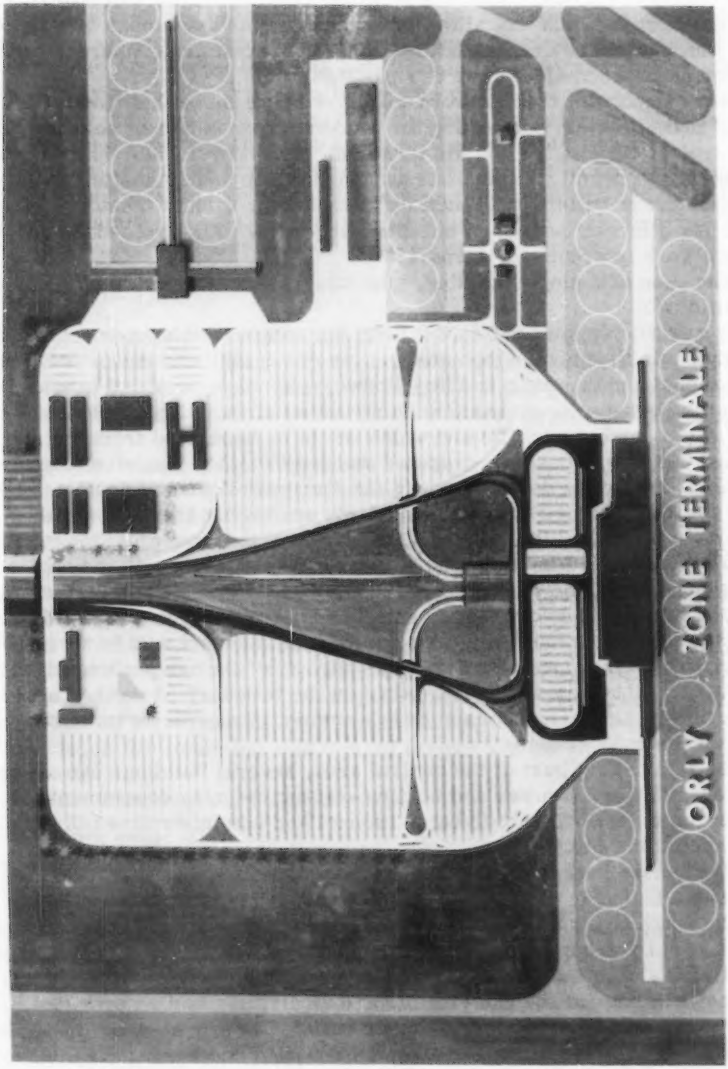


Fig. 2

- car parking areas,
- recreation area.

First, a small 40 room hotel which will be extended by the addition of 40 other rooms is planned within the terminal building. This will constitute a first experience which will allow us to consider the usefulness of a larger hotel which would be erected later within the central area, where a suitable location has been reserved for this purpose.

A very important road network will service all these facilities.

The main problem concerning the terminal area is that of selecting an adequate type of building for the air terminal. Was it preferable to erect only one building concentrating the international traffic and domestic traffic, or two independent buildings, especially designed for each of these two types of traffic, or a larger number of buildings according to the procedure adopted by the New York International Airport?

In the case of a single building, what kind of facilities could be included in this building?

For a traffic volume of 6 to 8 million passengers we have estimated that it was advisable to envisage the construction of a main building for the both international and domestic traffic. However, we have provided expansion by keeping the possibility of erecting an air terminal building which would be used for the domestic traffic and which would be separated from the main terminal building. It is also expected that the Common Market would give raise to an important development of the European domestic traffic which would justify the future construction of this second air terminal building.

We have preferred the concentrated solution, and have provided in the same building the installation of the operational services, technical and administrative services of the various airlines and Orly Airport. In a further construction phase, the control tower will be added to this group of buildings.

All the services required for the passenger transport will be then grouped in a single building, located between the apron and the car parking area.

An air freight station will be erected on the boundary of another apron.

The car parking areas consist of two symmetrical groups, on either side of the access road system.

In the North-East part of the central area, several buildings are under construction: they are a power and heating station; catering department for airlines; training facilities for flying personnel and administrative offices of the Air France Company.

On the North-West opposite side, we plan to arrange a recreation area, and eventually a hotel for passengers.

At the south of the terminal building, on the other side of the main apron, we shall erect a group of small buildings for the overhaul of airplanes belonging to airlines which are not furnished with large hangars at Orly. A more important building for the catering of various airlines is also provided. It will include many stores and shops. Another building is provided for the health service. You will find hereafter other information concerning the future air terminal building.

Car Parking Areas

While visiting the states we have been very struck by importance of the car parking areas located in the vicinity of the air terminal buildings. We have seriously considered the detailed lay-outs of these parking areas and

especially the system utilized for the collection of parking fees. At the present, we are considering the car parking areas of Orly airport. The car parking areas of the Dallas airport seemed to us especially well designed and adequate for separating the car traffic from the pedestrian traffic; it includes a central traffic area for pedestrians with a small fish bone type parking area, for cars, on each side of the area concerned. A single access road is arranged for the cars on the opposite side of the air terminal building. Only one keeper is required for the operation of this parking area.

On the other side, the pedestrians directly enter the building. This is an ideal lay-out which we plan to follow as closely as possible.

The aspect of large car parking areas, full or empty, is always unpleasant. At Orly we intend to set trees in alternate rows in our parking areas, in order to give them a more pleasant aspect and to provide shade in summer. In this car parking area approximately 5,000 vehicles will be parked.

Industrial Areas—Hangars

For the time being, the master plan shows a large industrial area located at the North of the field. The personnel and supply access to this area will be separated from the access provided for the users of the central area. In the future, other areas will be arranged in the North-Western part of the airport. Fig. 1.

The Northern industrial area includes a complex of hangars, maintenance shops, stores, snack bars for the personnel, and car parking areas, distributed between three air carriers: Air France, T.A.I. and T.W.A.

All the hangars are built with a steel frame; most of them are new. They were designed and built by the Paris Airport in 1953. They are a cantilever design. This design permits a maximum number of airplanes, of all types, to use a given hangar, since no columns are located in the opening of the hangar.

We have noted that hangars, designed according to the same cantilever principle, have recently been built in the States and especially at the New York International Airport. The French hangars and the American hangars are slightly different, in respect to the construction process, but the basic principle is the same. We think that this type of hangar will be very appreciated all over the world.

Their main dimensions are listed below:

- main beam span: 130'
- total width of the hangar: 180'
- head room: 48'

The hangars are surrounded with very important facilities. They have radiant heat utilizing pressurized water at 300° F.

At the present time, we are building a new hangar 1,000' long.

Internal Road Network

The road network of the central area of a large airport is often very complicated. All the secondary traffic roads connecting the various areas of the airport and passing through the central area, are sometimes mixed with the main traffic roads used by the vehicles servicing the air terminal buildings.

A problem associated with the above is the one concerning the signal system, which increases as the different types of traffic become more complex.

For studying the traffic in the central area at Orly, we call upon two French consultants who are specialists and who are especially well informed about American standards.

The results obtained from their studies are indicated on Fig. 1, which shows:

1. The end of the two fingers of the expressway on the both sides of the esplanade located at the North of the air terminal.
2. The network of the roads connecting the main traffic roads, the secondary roads and the car parking areas. These connections are made, according to the requirements, through underground or overhead systems, in order to avoid crossings.
3. Two parking areas on the airport esplanade, one on the departure side, and the other on the arrival side. Only the vehicles which have to stop at the air terminal will run along the air terminal front. Other vehicles will turn into parking areas before reaching the air terminal building.

In front of the main entrance of the building, between the two parking areas, a special arrangement is provided for the bus stop. This arrangement permits an increase of about 60% of the length of the exchange front between the road and the air terminal. Two other bus parking points will be also provided on the both sides of the building, departure side.

The problems raised by the connections between the roads, the air terminal and the car parking areas have been seriously examined. The investigations made by P.A.A. for its air terminal which is presently under construction at the New York International Airport, and by the authorities in charge of the survey concerning the Airport of Los Angeles, which is the American city where the ratio between the number of cars and the number of residents is the highest, are very interesting. It is too late now for modifying our Orly projects, but it would be interesting to know if the idea which consists in reserving a level for the vehicle traffic and another level for the pedestrian traffic, would be suitable for the future projects.

As a matter of fact when two different kinds of traffic must be separated (passengers and luggages, pedestrians and cars, for example) we begin first to attempt a level separation (passengers on the one side, luggages on the other side—pedestrians on the one side and vehicles on the other side). Beyond a certain volume of traffic this level separation is not sufficient and it is necessary to plan a vertical separation (passengers above, luggages underpedestrians above and vehicles under). As use of the private car increases, the vertical separation between cars and pedestrians will be perhaps the future solution to the problem, not only on the airports, but even inside of the town districts.

Connection Facilities Between Paris and the Airport

The transportation between the Orly Airport and Paris is at the present time made through the Highway No. 7 which runs on the former boundary of the airport.

The extension of the airport towards the West necessitated that this highway should pass over the axis of the field, in the middle of the central area and under the terminal installations. A detour surrounding Orly would have been much longer. An economical calculation has shown that it was more advantageous to cross the airfield below the airport grade and to build some

bridges than to increase the length of the Highway. The highway users also have a shorter and more pleasant trip.

In the future, this highway will continue to service Orly. However, the access to this road will be made chiefly through a section of the expressway coming from Paris, which is presently under construction. This expressway includes three sections: the first section will be connected to the Highway No. 20 (Paris-Toulouse and Spain), the second section will be connected to Highway No. 7 (Paris-Lyon-Marseille-Nice and Italy), and the third section will go directly to Orly. The purpose of constructing these new expressways is to clear the traffic congestion at the exit points and the suburbs of Paris. When this new road network is opened to the traffic, it will take only 15 minutes to go from Orly to the center of the left bank districts of Paris.

We have engaged an engineering office to study the users of our Orly and Le Bourget downtown terminals, in Paris. As the study has separated visitors and employees, we have been able to draw a sort of separating line, between the users going to Le Bourget and users going to Orly and to locate their departure and arrival points in Paris for each airport. We have evaluated, under various conditions, the time spent for travelling between the airports concerned and the various points. The results obtained have shown that no point located in Paris is at more than 30 minutes from Orly or Le Bourget, whatever may be the traffic conditions.

A servicing rail system for Orly has been also considered. At a short distance from the Northern area of the airfield is an existing railroad. It would be very easy—but expensive—to connect it to the airport. However, it has been shown that the volume of rail traffic on the South railways of Paris is such that the addition of new passengers would overload the existing railways. Under these conditions, this project was not considered, for the time being, and the study has been postponed.

Depressing the highway, the construction of the different sections of the expressway and the organization of the internal road network have necessitated the construction of 14 bridges, one to be used by the airlines, the others by the vehicles. They are made of prestressed concrete, except the bridge located under the air terminal building, which is made of conventional reinforced concrete.

The characteristics of these bridges have been the subject of long studies, with respect to their utilization.

The Air Terminal

Whereas the second World War stopped any commercial air transport in Europe, air terminals were continuously developed in the United States and numerous air terminals have been built during the last 20 years.

However, it was not possible for us to take full advantage from your experience, due to the essential difference existing between your air terminals and ours. In Europe, the traffic controlled by the Customs and the Immigration services is about 90% of the total traffic; while in the States, the proportion is reversed. Furthermore, the travellers leave your country for a foreign country without any other formality than getting the sailing permit, or passport which is not likely to be systematically checked in your air terminals.

We have surveyed and visited most of the American air terminals and we have found a complete line of various solutions, from the small one level air

terminal, to the multiple air terminals called unit terminals (New York International Airport), consisting of all types of air terminals including several levels. We have also found the most luxurious air terminals (Pittsburgh) and the most economical ones (Newark).

What conclusions could we draw from these surveys, which could be applied to our air terminals?

General Layout—Examinations—The Orly System

The simplest air terminals are the best ones, because they can be generally easily modified and extended. Every time a one level design is possible, the solution is simplified. We think that such a terminal is suitable for traffics ranging from 1 to 2 million passengers per year.

For a greater volume of traffic, a separation of passengers and luggage, by having two levels on the apron side of the terminal, is desirable.

On the other hand, on the town side only one level is required as the traffic volume remains within certain limits, as is now the case for Idlewild.

Until now the most practical system for getting the airplanes to the terminal is the pier or fingers system.

As of 1951, we have drawn these principles from a survey concerning air terminals already constructed and we have established on these bases the "avant-project" of the Orly air terminal, which is as follows:

On town side, a 1st floor where the ticket counter and the delivery bank are located in a large lobby. This floor is at the same level as a large esplanade.

At the centre of this lobby, a set of escalators permits one to reach the second floor, and the concession centre. From this point all the passengers go to the airplanes through two piers, the one at the East and the other at the West side the central part of the building.

This type of terminal would be an American domestic air terminal. But we had to consider the Customs and Immigration formalities to which the passengers are subject; and we have the "Orly system", which is as follows:

At the departure time: the passengers must be relieved of their registered luggages and the luggage must be inspected by customs as quickly as possible. To do this it is necessary to add, against the ticket counter, a small bench for the customs examination in order to have the customs officer inspect the registered luggages immediately after it is registrated. The luggage is then the responsibility of the airline company and it is immediately loaded in the plane.

The passengers remain with their friends or relatives and have free access to the 2nd floor where there is a large waiting and shopping lounge. Two cases may arise:

- domestic lines passengers
- international line passengers

The piers include on the 2nd floor two parallel galleries the one is used by the domestic line passengers and the other by passengers submitted to customs formalities.

On the 2nd floor, the domestic line passengers are directed to the piers gallery assigned to them. The other passengers cross the boundary through a control system where they accomplish the customs and Immigration formalities; consisting of an inspection of hand luggage, declaration of currencies and checking of passport.

At the arrival time: The operations are reversed. The domestic line passengers arrive in the main lounge through the gallery assigned to them in the piers and go down into the 1st floor to get their luggage.

The passengers of the international airlines arrive through the other gallery and cross the control center (Immigration and customs formalities for hand luggages and currencies). They meet their friends and go down to get their luggages. The customs inspection of the luggages is performed on a delivery bench when the passenger is present. This system has been already tested in the Orly South air terminal where it has been found satisfactory. It has been also tried and adopted in the new English airport of Gatwick, for departure gates and it has been found in this airport that it would permit a saving of about 30% of the area of the terminal. A formal report prepared by the British Ministry of Civil Aviation recommends the application of such a system for all the air terminals to be built in the United Kingdom.

We shall complete this description by two remarks, i.e.

a) The main interest offered by the Orly system is a "trickle" loading, the passengers going individually and freely from the ticket-counters to the gates, without being grouped according to the flights, in a specified point, for the luggage inspection. This trickle loading system which is efficient in the States, has been much discussed in Europe because of the inspection and formalities.

   A certain evolution is presently noted; it has been understood that the large volumes of traffic expected in the near future could only be satisfied using a trickle loading system. A package loading system gives raise to bottlenecks and jamming which is to be avoided in a good operation during peak hours.

b) With the Orly system a European terminal, including customs office, can be easily transformed into a domestic traffic air terminal; in the latter there is no large rooms for customs operations; the inspection facilities are conducted on furniture which would be easily removed if the inspections are cancelled. In any case it is easy to modify such installations and to adapt the air terminal to the modifications which would result from changes within the characteristics of the international relations.

How Many Level?—For Orly Only One Level on the Town Side

Some of the American air terminals include two levels on the town side: the lower level is assigned to the arriving passengers, and the higher level to the departing passengers.

The San Francisco air terminal is of this type.

The two level system, on the town side, has been experienced in some European air terminals, Zurich for example.

For Paris we have estimated this system too complicated as we think that it will present some risks of jamming of cars at the 2nd floor, before the departure hall (we have seen a big traffic jam at the Houston air terminal). We believe it is preferable to use only one "town side" level at the ground level with a very large esplanade, as it is the case for the most of the French railway stations. This is the normal passenger and luggage exchange level between ground transportation means and the building.

The engineers of The Port of New York Authority have reached a similar conclusion: the arrival building of the New York International Airport includes only one level, town side, this level being the one of the 1st floor.

How Many Level?—Two Levels on the Apron Side

On the apron side the main problem is the separation of the passengers and the luggages. We noted two systems used in the States: they are explained below:

a) A vertical separation—the passengers are circulating on the second floor and the baggage is handled at the apron level. We retained this system for Orly.

How to Make Money?

The commercial experience carried out within the American terminals has been very useful to us.

We have learned from your experience that it was necessary to study carefully the rentability of an air terminal and to select adequately the concessionaires. It has been usually said that an air terminal should include a large number of attractions and facilities, of various types. Your experience has shown that many of them were not profitable and occupy too much space in the building.

At Orly the passengers will find in the gallery the most interesting shops such as newspapers, tobaccos, perfumes, fancy goods, usual gifts, liquors. They can be purchased "out of duty" in the waiting lounge under custom control some typical French products. The 4th floor of the air terminal will be assigned to the restaurant and the terraces will be accessible to the visitors.

The restaurants are only of two types; a coffee-shop with a snack bar and a first class restaurant. A cocktail lounge including a bar will be located between the two above categories of restaurants. A grill-room will be installed in a corner of the coffee-shop.

Generally your experience has prevented us from overdoing the importance of the concessionnaires, looking for the maximum of profitability for the whole area of the building.

We have in France another important source of profits: the passenger tax. This is a fee due for the use of the installation arranged for the passenger movements.

This fee is collected by the air carriers who pays it to the Paris Airport Authority. Some airlines collect it from the passengers other do not and pay the fee themselves.

In 1958 the revenue produced by this fee amounted to more than $1,000,000 i.e. approximately one dollar per departing revenue passenger.

Orly Air Terminal Project

Now I would like to show you the drawings of the Orly Terminal Building. Figs. 3, 4, and 5.

The building includes a central body and two piers.

Only one level is provided on the town side for the check-in and the delivery of luggages and two levels, on the apron side,—the luggages being on the first floor and the passengers going up to the 2nd floor; from this point they go to the planes following the galleries located inside of the two piers parallel to the front face of the air terminal.

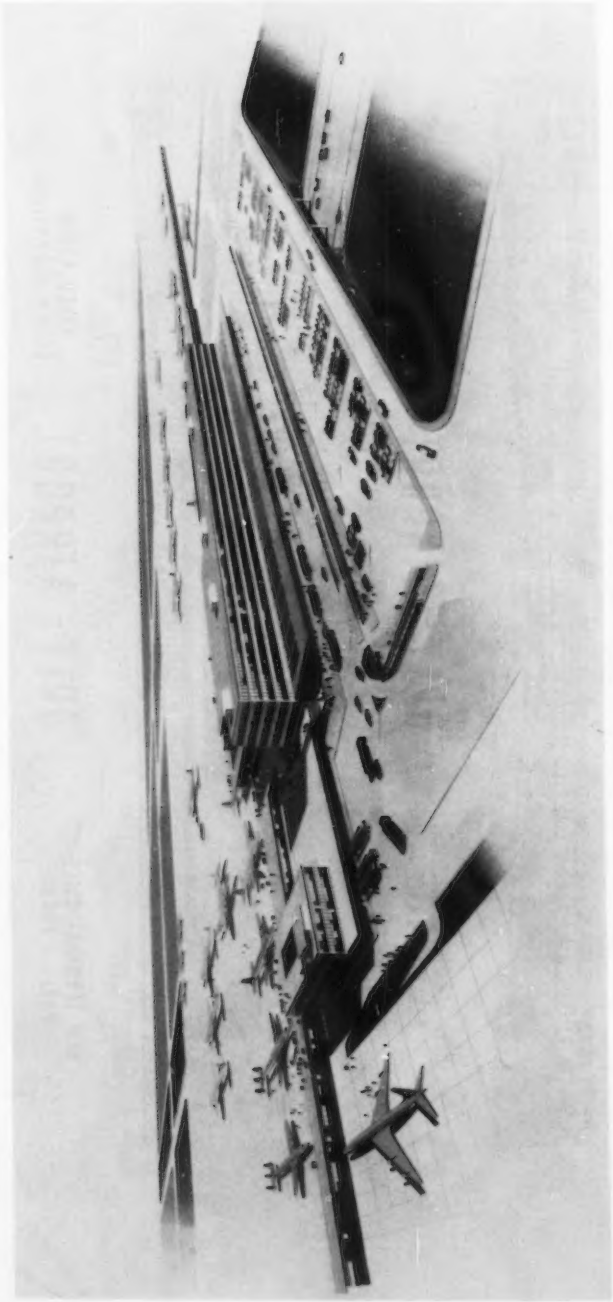
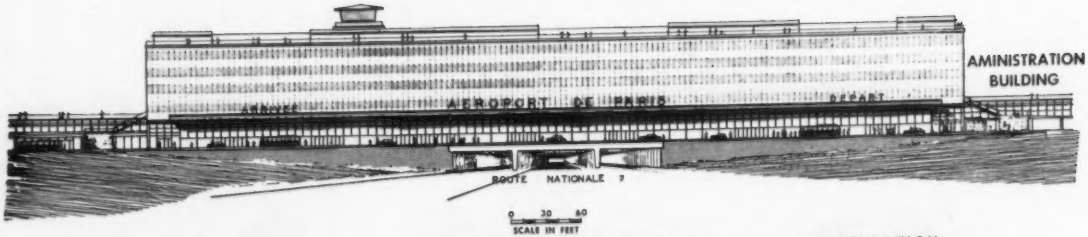


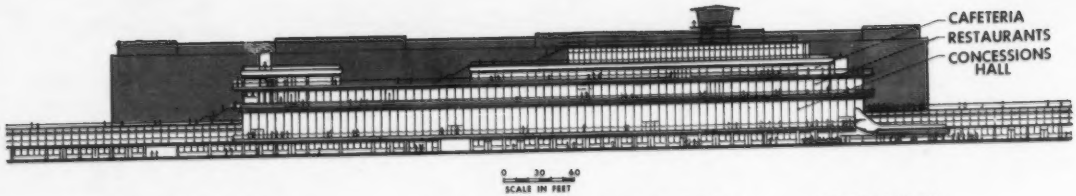
Fig. 3



NEW TERMINAL BUILDING
PARIS - FRANCE

ORLY - AIRPORT

CIRCULATION
NORTH ELEVATION



NEW TERMINAL BUILDING
PARIS - FRANCE

ORLY - AIRPORT

CIRCULATION
SOUTH ELEVATION

Fig. 4

AT 3

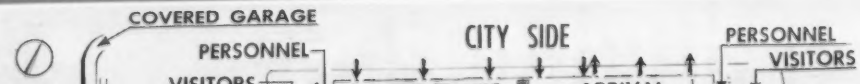
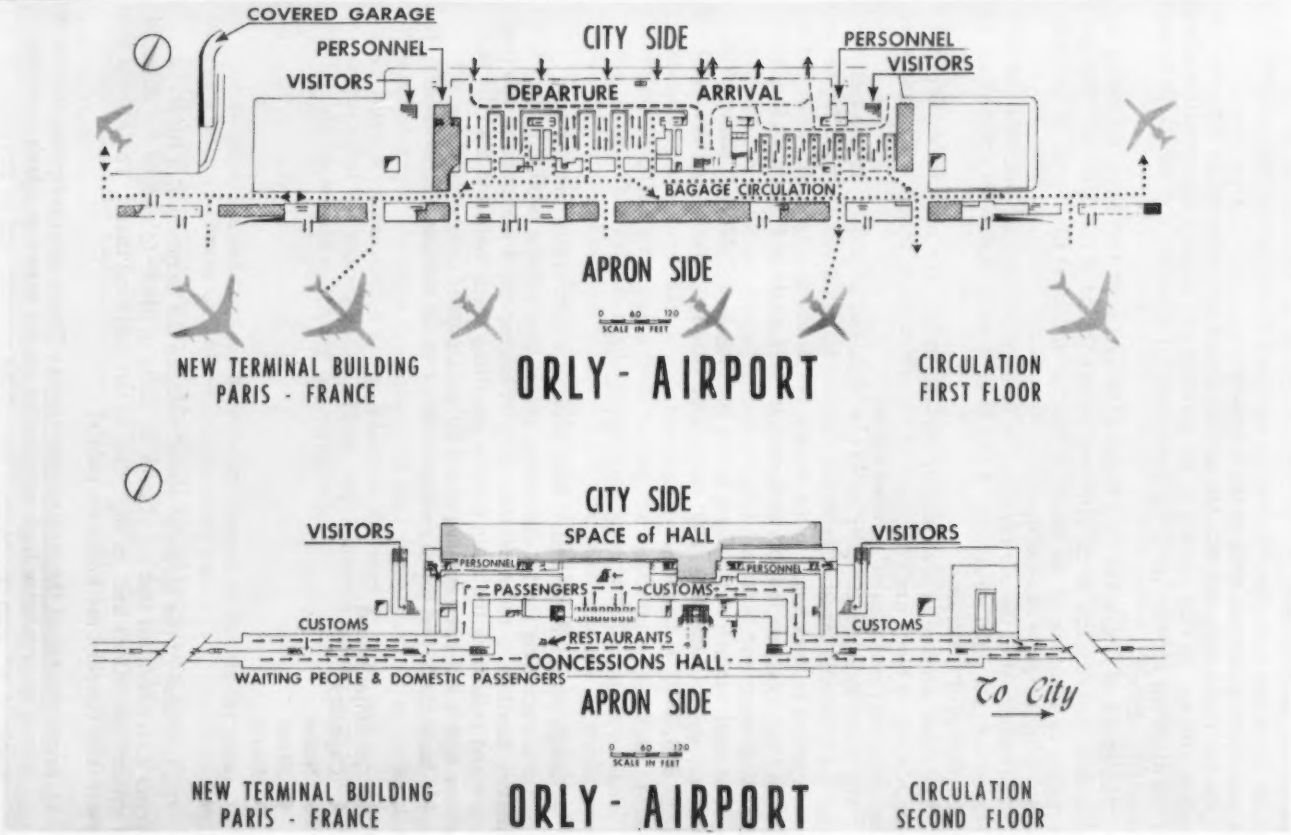


Fig. 4


COVERED GARAGE
PERSONNEL
VISITORS
CITY SIDE
DEPARTURE
ARRIVAL
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VISITORS
BAGAGE CIRCULATION
APRON SIDE
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SCALE IN FEET
NEW TERMINAL BUILDING
PARIS - FRANCE
ORLY - AIRPORT
CIRCULATION
FIRST FLOOR
CITY SIDE
VISITORS
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PERSONNEL
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CUSTOMS
RESTAURANTS
CONCESSIONS HALL
WAITING PEOPLE & DOMESTIC PASSENGERS
To City
APRON SIDE
0 60 120
SCALE IN FEET
NEW TERMINAL BUILDING
PARIS - FRANCE
ORLY - AIRPORT
CIRCULATION
SECOND FLOOR

Fig. 5

The waiting room is located on the 3rd floor, under the custom control for the transit passengers.

On the apron side, the 4th floor is assigned to the restaurants. A cafeteria is also located here as well as the terraces.

On the Paris side, the 4th, 5th and 6th floors are occupied by the administration offices. In this portion of the building are located the operation offices of the different air carriers, the governmental agencies and the Paris Airport Authority offices.

The Building is erected on a framework having 27 feet bays, providing a very easy distribution of the different rooms inside of the building. The air terminal is adjacent, at the South, to the apron and, at the North, to the esplanade. It is laterally extensible.

The basement of the air terminal is made of reinforced concrete and the framework is a steel structure. 6,000 tons of steel have been utilized for the construction of the frame.

The front surface is enclosed by curtain-walls. The curtain-walls of the administrative block are composed of enameled glass panels with glass wool insulation and mullions of stainless steel.

The south face and the pier faces are enclosed by panels, frame and windows elements made of anodized aluminum. This system used for the skin construction is very usual in the States, but is not so often utilized in Europe. We, in 1953, constructed the first curtain-wall made in France, at the South Orly temporary air terminal.

The total surface of the floor in the building is of 1,320,000 square feet. Its capacity is 14,000,000 cubic feet. This building entirely equipped will cost about $20,000,000.

Jet Age Problems

Although many articles have been published concerning the various problems regarding the jet operation, and although these problems are, in my opinion, familiar to the American Airport Engineers, I will summarize them below and indicating the main trouble resulting from them and also the solutions which has been envisaged for Orly Airport.

We have classified these problems into five (5) categories, which are as follows:

1. Quadrijet speed
2. Capacity
3. Noise
4. Blast
5. Smell

Speed

The increase of the airplane speed reduces the duration of a flight. It seems then essential that all efforts be made in order to reduce the duration of ground operations and, in any case, to not increase them. The efforts must essentially concern the following points:

a) Improvement of the taxiing operations—These improvements will be obtained by arranging high speed exits on the runways, which make an angle of 30° with the central line of the runway, and by providing by-pass pads at the entrance points of the runway.

b) Reduction of the duration of the apron operations—The apron operations can be accelerated by the installation of a hydrant system, the mechanization and the organization of the ramp-service, according to an accurate layout for each airplane's requirements. In this connection, we have noted the perfect organization of the Fort Worth Airport.

At Orly, and in the most important European Airports, these considerations are not so important as in the States, due to the fact that the transit flights are not as numerous as terminal flights. At Orly the installation of the hydrant-system has been foreseen at 8 berthes for the big jets, during the first improvement phase.

c) Reduction of the travelling time of the passengers inside of the air terminal—We have already pointed out that it was suitable to provide a trickle-loading system from the entrance of the terminal to the airplane and vice-versa. The ideal solution would consist of allowing the passengers to enter the plane individually as soon as the latter is on its parking place, as they do in the Railroad stations.

d) The execution of the formalities has been very accelerated at Orly due to the Orly system—The loss of time is frequently caused, during enplaning and deplaning, by the time required to load and unload the luggage.

Two systems can be considered in order to reduce the duration of these operations; the first one consists in facilitating, as much as possible, the access to the luggage compartment inside the planes, or in using containers; the second one would consist in generalizing the arrangements adopted for certain types of airplanes, the Martin 404, the Convair and the Caravelle, for instance, in which the passengers place their luggage on racks installed at the entrance of the plane. This system would simplify considerably the operation and would gain time not only on the apron, but also inside the air terminal, where the time spent for registration and delivery of luggage would be reduced for many passengers.

Capacity

The quadrijets have an approximate twice the capacity of the conventional airplanes. As a double number of passengers are processed at the same time, it is necessary to increase the number of the ticket-counters, to adopt an adequate luggage classification and an adequate delivery system, and to increase the capacity of the waiting room. These requirements can be very important for the air terminals which are not extendible.

Noise

The defense against airplane noise with respect to the air terminal, requires a serious survey of the acoustical problems.

At Orly we have provided a systematical use of very thick glass panels, almost 3/4 inch, for the face of the central part of the air terminal building, on the apron side. The main rooms are protected with double doors. All the ceilings are of the acoustical type in order to realize a good interior noise absorption.

The waiting room provided for the transit passengers has no openings directly on the apron. As a matter of fact, we are of the opinion that these

travellers will appreciate relaxing within an atmosphere as quiet and comfortable as possible.

Blast

Blast fences will be fitted around the jet berthes. The masonry walls of the first floor of the air terminal building has been covered with ceramic tiles which are very easy to clean.

For the time being, no special device has been provided for the passenger protection, between the gate and the airplane. This problem is still under consideration. It has already been mentioned above.

Smell

The problem concerning the small seems to us probably more important than the one concerning blast and noise. Two difficulties have been encountered:

- to prevent smell from entering the building.
- to supply the air terminal fans with deodorized air.

a) In order to prevent smell from penetrating inside of the air terminal we have reduced the number of openings and provided large ventilation installation so designed that the air terminal is pressurized (0,08 inch of water approximately. This pressure is low, but it is difficult to obtain and expensive too.)

b) In order to supply the fans with pure air, we have performed tests on scale models. These tests have shown that it was impossible to find an adequate fresh air inlet at any point, in the vicinity of the building, which will be surrounded with contaminated air on all its faces and at varying heights pursuant to the direction and the strength of the wind. We have deodorizing filters in the vent stations. For the time being we have retained the solution of using activated carbon. Some tests, based on the use of an "air-wick" spraying, are also provided.

* * *

Summarizing, the coming of the jets has involved, for the Paris Airport Authority, the following studies:

Concerning the Apron: survey of the hydrant-system installation; study of blast fences; study regarding protection of the personnel on the apron.

Since we are receiving at Le Bourget the Pan American Boeing 707, we systematically perform various experiments concerning the conditions under which these jets are flying, concerning their parking operations, and the efficiency and location of various types of blast fences, and also concerning all the attached problems which are likely to be encountered.

For the time being, due to lack of the adequate equipment, we were not able to perform backwards towage tests and we allow the jet to taxi by its own means. Therefore, we have decided temporarily to extend to 200' the large jet berthes provided at Orly. Nevertheless we shall carry out the studies and we shall look for any documentation concerning the towage operations of these airplanes, and especially regarding the backwards towage.

For the time being, we did not adopt any special arrangement for the passengers to travel under a covered area, between the air terminal and the planes.

Concerning the air terminal: We are taking additional actions for the protection of the building against the noise by installing very thick glass panels and absorbing coatings.

The air terminal will be as soundproof as possible.

The vent installation has been the subject of special studies in order to have the building pressurized. Deodorizing filters have been provided.

The construction method of the curtain walls, which can be easily removed, will permit us to add, in the future, all the fixed or mobile elements which could be required, in consideration of the operation conditions of the jets.

We have to emphasize that the Jet Age does not give raise to serious problems on our Paris Airports, except the problem concerning the individuals living in the immediate vicinity of the airports concerned. We lead a strong action to the pilots and the carriers for the setting of special take off procedures and the respect of same. We have organized a special office which is in charge of the studies pertaining to the neighborhood and which receives the complaints of the neighbors. This office issues, in a special bulletin which is sent to them without any charge, the various information which would be interesting to them.

In so doing, and due to technical and psychological action, we are in the opinion that we can prevent bad reactions and that some inconveniences, which are for the present time under study and very difficult to avoid, can be supported.

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Journal of the
AIR TRANSPORT DIVISION
Proceedings of the American Society of Civil Engineers

AN OPERATOR'S EXPERIENCE IN AIRPORT OPERATIONS WITH JETS

R. J. Sutherland[1]

Here is a quick overall view of some of our operation problems:

Runway Lengths

At New York International Airport, the Port of New York Authority extended Runway 13R-31L to 11,200' and Runway 7R-25L to 10,000'. At Chicago, the City did a remarkable job in reconstructing and extending Runway 14R-32L to 8838' in a period of about three months. At Los Angeles, the City extended Runway 7R-25L to 10,000'. At San Francisco, the City is now extending Runway 28R-10L to 9500' and Runway 1R-19L to 9000'. At some problem airports extensions are needed.

Runway Grades

Our experience at one of our major airports emphasized the need for uniform runway gradients. This particular airport had several depressed areas due to settlement near the center of a main runway. These depressed areas had the effect of causing our jets to become airborne before actually reaching adequate take-off speed with the result that they would settle back on the runway with a loss of acceleration and the take-off would then become critical. This condition has since been corrected.

Holding and Bypass Areas

The lack of these facilities adjacent to the ends of all runways is a serious handicap. Although as a general rule, we do not run-up our jet engines prior to take-off as with piston engines, adequate holding and bypass areas are required to permit jet aircraft to bypass piston engine aircraft running up or waiting for ATC clearance.

Removal of Snow and Ice

This past winter during a Boeing 707 take-off on a runway covered with an accumulation of slush acceleration, was slowed down to a point where the

Note: Discussion open until December 1, 1959. To extend the closing date one month, a written request must be filed with the Executive Secretary, ASCE. Paper 2113 is part of the copyrighted Journal of the Air Transport Division, Proceedings of the American Society of Civil Engineers, Vol. 85, No. AT 3, July, 1959.

1. Director Airport Flight Facility Development, American Airlines, Inc., New York, N. Y.

take-off became critical. After landing at the destination, an inspection revealed minor damage to the underside of the plane from slush being thrown up against it. This taught us two things. First, that effect of slush on acceleration of the jets due to their higher take-off speeds is so pronounced that runway length can quickly become critical. Secondly, at high ground speeds, slush can damage the airplane. As a result, our operating manual now prohibits take-offs when accumulations of snow, slush, and broken ice are greater than 1/2 inch.

Terminal Area Blast Fences

Our preliminary planning indicated that terminal area gate separator blast fences would be desirable, but that their most important function would be to deflect high frequency compressor noise eminating from the front end of the jet engines, rather than blast protection. Experience indicates that the blast protection is much more important. Exhaust velocities as high as 180 knots have been registered at breakaway with a fully loaded jet where a turn is required to get out of a gate position. Such blasts can cause damage to facilities and disrupt operations at adjacent gates. We first used concrete blast fences but found them to be unsatisfactory because they are susceptable to normal concrete cracking and damage from ground equipment collision. As these cracks progress, it is quite possible for pieces of the blast fence to be dislodged by the blast with possible serious damage or injury. We now use steel blast fences for all installations.

Noise Problem

Noise has been less of a problem than anticipated. Suppressor equipment has reduced flight noise to a point where it compares favorably with propellor driven aircraft. Preferential runway, selected flight patterns, and use of reduced power have further cut down annoyance.

Another possible noise problem is ground runup during maintenance operations. We are now experimenting with special ground suppressor units. The unit we are presently using is quite bulky being some 38 feet in length and is quite awkward to change from one engine to another. We are hopeful a smaller unit will be developed that will improve this condition.

By cooperation with airport managements, we believe both flight and ground noise problems can be minimized.

Foreign Object Ingestion Damage

Our experience to date with this problem is much better than we anticipated. However, it is still considered a possible critical problem and we have been negotiating with airport managements to provide pavement sweeping service on the following basis:

a) Ramp areas and taxiways to be swept daily.
b) Runways to be swept once a week.

We have met with very little success to date but feel that as the number of jet operations increases, ingestion problems are bound to increase and we hope by that time regular routine sweeping programs will be underway.

Passenger Loading

We believe that the most efficient and convenient loading system for an airplane, with the passenger capacity of a 707 or DC-8 is to taxi the airplane nose-in to a second level terminal departure lounge where a short enclosed bridge connects the front door with the departure lounge and longer swinging enclosed bridge serves the rear door. We have just recently completed the installation of the first front door bridge at San Francisco and from all reports, it is working out even better than expected. We plan to use both front and rear door loading bridges wherever the terminal configuration is adaptable.

Passenger Acceptance

The public acceptance of the 707 has been remarkable. Average load factors have stayed well up into the 90 plus bracket. It is still hard for some passengers to believe they can travel from coast to coast in 4-1/2 hours.

Engineering has made all this possible and the role of the civil engineer in the development of ground facilities for these new jets should not be overlooked.

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Journal of the
AIR TRANSPORT DIVISION
Proceedings of the American Society of Civil Engineers

EXPERIENCES IN AIRPORT OPERATIONS WITH JET AIRCRAFT

Peter W. Ball[1]

The scope of this subject "Experiences in Airport Operations with Jet Aircraft" is, somewhat extensive as far as B.O.A.C. is concerned. However, these remarks will be quite brief, because they will deal principally with our experiences at the International Arrival Building and Wing Buildings at Idlewild, New York. B.O.A.C. has approached the handling of these aircraft as if they were no different from conventional types. For the most part this approach has proved to be realistic for the three turbine powered aircraft operated to date, namely the Vickers Viscount, the Bristol Britannia and the De Havilland Comet.

Neither the Britannia nor the Viscount has presented any specific problems. As far as ground handling at terminals is concerned we have treated these two types of aircraft in exactly the same way as piston-engined aircraft.

Because the turning circle of the Britannia, which is equipped with a bogey undercarriage, is somewhat larger than, for example, a DC7C, there was a short period after this aircraft was first introduced when maneuvering on the ramp onto certain parking positions—especially those in corners—did mean that the aircraft had to be backed up into position by tug. This situation quickly settled down when pilots and ground staff became accustomed to the new aircraft.

As for the Viscount, which we have operated for some of our Caribbean services, there have been some occasions on the longer sectors when the airport traffic delays necessitated holding the aircraft on the departure spot until its turn for take-off came near. A simple procedure was worked out with the Port of New York Authority and the tower to deal with these situations.

As far as the Comet 4 is concerned, it is our contention that we have successfully operated this aircraft at New York International Airport—arriving at and departing from the International Arrival and East Wing Building—without any difficulty or inconvenience to others. You will recall that B.O.A.C. started the first commercial jet Trans-Atlantic service with the Comet 4 on October 4, 1958.

From May 1952 B.O.A.C. operated the Comet 1 along the routes from London to South Africa and to the Far East, through fairly busy terminals,

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1. British Overseas Airways Corp., New York, N. Y.

without creating any difficulties. The Comet could be fitted into any aircraft terminal pattern, along with piston-engine and jet-prop aircraft.

In saying that a pure jet can be fitted into a normal terminal pattern, we are not overlooking the need for some special precautions and certain new procedures.

Spotting of the aircraft is important. At Idlewild, for example, we bring the Comet onto a gate nose first so that any jet blast is directed away from the buildings and ground equipment. For departures of the Comet from the Terminal Building we ensure that all ground personnel engaged in the operation have been specially trained in the handling of this type of aircraft. Above all they must be vigilant and there must be constant supervision by those in charge to ensure not only that the aircraft is properly positioned at the gate, but that ground equipment has been moved to a safe distance from the path of the jet blast as the aircraft turns.

By adopting such measures we have found that we can successfully operate the Comet 4 from the east finger at New York International without difficulty. I should mention that as a temporary measure we are required to tow the aircraft away from the building for start-up at a hardstanding nearby. This procedure is hampering our operation somewhat and we believe it to be quite unnecessary. Besides it is laborious and time-consuming and causes approximately ten minutes delay in the departure of the service.

Obviously as the number of jet aircraft increases the need for vigilance becomes greater and co-ordination of engine starting by operators on adjacent gates becomes more important. Airport authorities and the airlines should jointly give considerable thought to evolving carefully timed procedures and methods for ensuring close supervision of ramp operations before jumping to a conclusion that blast fences or similar structures are necessary. Blast fences protruding on to the ramp are undesirable and we like to think they would not prove to be necessary.

A great deal can be achieved by the indoctrination of pilots on the subject of jet taxiing at terminals. We have carried out certain tests in conjunction with the Port of New York Authority at Idlewild and have demonstrated that a fully laden Comet 4 can be departed from the gate position under its own power, using as little as 10.62 per cent of total available thrust. The pilot, therefore, can do much to help the situation by "easing" the aircraft away from the gate position—and it is our contention that pilots will conscientiously do this and that it presents no problem.

A word about safety of airport personnel generally—experience has shown that all personnel soon become accustomed to jet aircraft maneuvres on the ramp and that they themselves guard against getting into any danger area in the same way as they guard against walking into a turning propeller. With the advent of bridge loading from the second deck level, no passengers will be walking on the ramp. It is our opinion that the airport and airline personnel and that of the service companies who work on the ramp will be able, as a result of their day to day acquaintance with jet aircraft, to take care of themselves and that no special arrangements are necessary for their safety, other than normal training in the ground operations of jet aircraft.

B.O.A.C. is looking forward to taking delivery within a few months of its fleet of Boeing 707-436s equipped with Rolls Royce Conway 505 by-pass jets. With the continuing and established pattern of cooperation which has long existed between airport authorities and the airlines, we confidently expect to conduct our future jet operations at airports with the same degree of success as in the past.

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EXPERIENCES IN AIR TERMINAL OPERATIONS WITH JET AIRCRAFT

Randall W. Kirk[1]

The basic requirements of the ideal airport terminal are:

1. Passengers should not have to walk a distance of greater than 600 feet between their surface transportation and their seat in the aircraft and all of such walk should be completely protected from the weather. There should be no long corridors or stairways and the route should be direct and obvious;
2. The airline passenger should not have to carry his baggage or hire the carrying of his baggage more than 75 feet from surface transportation to check-in point;
3. Passengers should be able to check-in without waiting;
4. The maximum check-in time should not exceed three minutes;
5. On arrival baggage delivery speed should correspond to walking time for the passenger from the aircraft to the claim or Customs area, that is, the first baggage from a flight should arrive in the claim area by the time the first passenger is able to walk to it and the last baggage should be there by the time the last passenger has arrived from the aircraft;
6. The maximum carrying distance from the Customs or claim area to the surface transportation should not exceed 75 feet;
7. The terminal configurations should be such as to permit the aircraft to be taxied in and out of its gate position and facilities should be adequate to permit transit or quick turnaround servicing of the aircraft on the gate.

With regard to towing, we believe this a regressive step in an age of great progress which reminds one of the flying boat era when it was necessary to pass a bow line from the aircraft to a launch or to the dock to permit the aircraft to be maneuvered into a moored position. With the number of aircraft movements involved, the minutes in lost ground time due to towing operations add up to an incredibly large figure.

Pan American is currently utilizing the principal terminals of Idlewild, London Airport North, Paris - LeBourget and Rome - Ciampino. At the

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1. Mgr., Ground Operations, Pan American Airlines, New York, N. Y.

Idlewild Departure Terminal we are using two gates on a finger located about 300 - 500 feet from the point of passenger check-in. Concrete blast fences have been installed on three sides of these two gates which limit the clear ramp surface to an area of about 193 feet sq. This area is too small for adequate taxi-in taxi-out handling of the jet aircraft without blast fence protection. Apart from this, the blast fence limits access to the area. If top-off fueling is being accomplished on the left side of the aircraft, the fuel truck must be placed so close to the aircraft as to preclude use of the forward loading door. The current required procedure for these gates is, taxi-in, load, start two engines, tow out to taxi strip and cross bleed to start the other two engines. We are hopeful that the early installation of steel fences at these gates will permit the return to taxi-out operations.

Taxi-in is a relatively minor problem as the aircraft is generally light and its rolling inertia reduces the need for the application of high thrust. With respect to taxi-out, break-away thrust is the most critical factor and it is a highly variable one. It is affected, of course, by the weight of the aircraft and by ramp depressions which may exist for drainage purposes. In addition, however, pilot technique is very critical as the thrust requirement for a very gradual acceleration from a standing start is much lower than for a rapid break-away. Finally, an important factor is the size of the gate position. In this respect the inadequately sized gates at Idlewild require the nose wheel to be turned full over prior to the aircraft's moving. This not only requires greater total thrust but involves an eccentric distribution of power with the greatest power on the critical side toward the finger. If adequate gate size is available, or if the aircraft is not prohibited from crossing through an adjacent gate by the positioning of blast fences, it may roll forward on break-away and then accomplish a gradual turn with much less thrust requirement. Based on experience to date, we recommend a gate size of 240 feet for the B-707 or the DC-8 with no fences between gate positions and a parking position approximately 30 degrees nose out. While some disturbing incidents have occurred as a result of blast at gates, we believe this can be eliminated by better ramp control and discipline of equipment and personnel. Up to this time individual airlines have been expected to exercise the discipline on the ramp but in high activity areas we believe a more highly co-ordinated control will be required.

With respect to jet noise at the gates, this has not been a serious problem to date as the high intensity noise is of relatively short duration and even flimsy building structures have been shown to substantially reduce noise impact.

At the International Arrivals Building at Idlewild, aircraft are being taxied-in and out at the outer gates without blast fences and without serious incident. At the present time a series of tests is being conducted including taxi nose in and tow out at the innermost gate positions.

At LeBourget Airport in Paris, we find the best jet terminal operating conditions of anywhere on the present routes. (While Orly Airport is our normal base of operation, we were obliged to use LeBourget temporarily due to runway/noise considerations.) Here we are able to taxi-in and out adjacent to the terminal building providing maximum convenience to our passengers who are able to proceed to the immediate vicinity of the aircraft in a covered glass enclosed finger. The Aeroport de Paris has installed a blast fence along the portion of the terminal side of the gate as well as an extension outward at the end of the gate behind the aircraft. This blast fence is apparently a test

installation and does not preclude taxiing straight out from the parking position. The other two airports at which we operate, London North and Rome - Ciampino, are temporary facilities and at both these locations we are obliged to park the aircraft on an apron located away from the terminal building and it is consequently necessary to provide bus transportation for the passengers, in the case of London, or walk the passengers a substantial distance, as at Rome. These terminals, temporary though they may be, must be considered unsuitable for jet operations in terms of the desired objectives. We are confident, however, that the new facilities planned for the long-haul terminal at London Central and under construction at Rome - Fiumicino will provide excellent jet operating terminal facilities.

The terminal we are constructing at Idlewild we expect will equal or better six and a half of the seven objectives previously stated for the ideal terminal. The one half objective which we have failed to achieve involved the sacrifice of an operational convenience in favor of passenger comfort and convenience considerations. In order to have gate positions located close to the building entrance and also under the weather protection of the building umbrella, it was necessary to taxi the aircraft nose in very close to the building, which in turn necessitates pushing the aircraft out to a starting position.

We should like to emphasize the importance, where transit or quick turnarounds are involved, of the ability to do servicing on the gate between arrival and departure. With this facility at way stations we have been able to make refueling transits at Gander in 18 minutes block to block and 24 minutes air to air and the speed of air transportation is better served thereby.

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AIRLINE EXPERIENCE IN AIRPORT OPERATION WITH JET AIRCRAFT

Marcy B. Fannon[1]

There are areas in which we, TWA, believe marked improvements can be made to cater to the jets' special requirements, based on our experience to date. These are the general airport arrangement—particularly in regard to ramp layout, our experience with interim facilities and equipment for passenger handling, our experience in servicing the airplane, and our experience from the over-all operational standpoint, to highlight troublesome areas in regard to providing an on-time operation.

On March 20 TWA inaugurated service with a daily New York - San Francisco schedule. To date this is 62 round trips or 124 flights. On April 9 TWA phased in a daily Chicago - Los Angeles service. To date this is 42 round trips or 84 separate flights; and on April 23 a daily New York - Los Angeles nonstop was added. To date this is 28 round trips or 56 flights. On May 1 a second daily New York - Los Angeles nonstop was added. To date this has been 20 round trips or 40 separate flights.

Our total jet experience so far has been 304 schedules, some 640,000 plane miles of service—of course, not including training requirements. These schedules are currently provided with five operating units, plus at least one additional unit wholly assigned to either flight or maintenance training. By early August, TWA will add the cities of Washington, D. C. through Baltimore (Friendship), St. Louis and Philadelphia, to its jet service.

Now, what will help TWA provide a better service?

First, in the general area of airports and in particular, ramp layouts, so far we have found no two arrangements alike, which at the onset to a degree was anticipated, but nevertheless complicates ground handling. Since we advocate taxi in, taxi out, not having adequate ramp area for jets has necessitated minor modification to this premise depending upon the specific circumstance. It has also required advancement in procurement of a few tractors because more station towing has been required, either as a direct result of inadequate facilities or due to local airport authority rulings, lacking completed facilities for jet operation.

For example, at San Francisco we taxi nose-in to the gate and deplane. Since San Francisco is a terminating station on our system, we've allowed

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sufficient time to reposition the airplane tail-in by tractor for servicing and enplaning. Engines are started in this position and the airplane taxies directly out. Should our assigned jet gate not be available, we then use the alternat position at the end of the international arrivals finger. At this location the authority does not require repositioning; therefore, the more flexible taxi in and out is utilized.

At Los Angeles we've had to resort to a temporary procedure until our interim jet gates become available. These interim gates should be ready by June 1. They will serve until the entirely new satellite terminal arrangemen becomes available—we hope by mid-1960.

Our procedure until June 1 is to taxi in and park at an oblique nose-in angle, about 45°. Deplaning, servicing and enplaning is accomplished in this position. A tractor is then affixed, engines started, and with idle thrust, the airplane is pushed out to a taxi line, the center-line separating TWA's finger from the adjoining carrier. At this location the tug is detached and the airplane taxies out.

After June 1, two interim but newly constructed jet gates will be available at the end of our finger. A passenger hold room is also under construction at this location. Since these gates are unobstructed by other aircraft movement, we can then resort to our basic premise of taxiing in and out, min mizing ground time.

At O'Hare we're in relatively good shape mainly because of the low total level of operation at the moment. Current handling adheres to the premise o taxi in and out. As we add jet service and build up our total level of operation, facilities at O'Hare will be completely inadequate. For this reason we've embarked on another interim program—that is, to add concrete and terminal facilities to handle this increase until the master plan takes over. These interim facilities should be available by August of this year.

At Idlewild preferential gates are not available, so we share with another carrier because of the status of airport development. At Idlewild, we taxi in, make about a 180° turn and park approximately parallel. At departure we ca start at the gate; however, all movement is by tractor. The airplane must be towed out some 800 to 1000 feet before the tug is detached to allow taxiing. This type handling is, of course, showing up in our ability to get off on time. Of our stations so far handling jets, Idlewild shows up as requiring the greatest ramp dispatching time. Some improvement is anticipated because we are planning to utilize space at our assigned new unit terminal location, which has been leased for the past years to another carrier.

Fixed servicing facilities, particularly fueling and electrical ground powe are practically a necessity at major level stations. Such fixed facilities should also be incorporated at hangar sites at selected stations where either the carrier's major maintenance is handled or in conjunction with a high leve of operation frequency. With us, these domestic stations are:

Idlewild - ramp and hangar sites
Los Angeles - ramp and hangar sites
San Francisco - hangar site only
O'Hare - piped to hangar site only
St. Louis - ramp only
Pittsburgh - ramp only

Taxi in and out operation minimizes ground time. With this conviction, a because specific terminal plans best accommodate the plane parked either

obliquely nose-out or parallel, we've evolved the location of a pair of hydrant outlets that can equally accommodate the airplane in either position. From our standpoint this is extremely pertinent because until other methods of passenger loading, like bridges, are proven fully practical and economically feasible, we retain the flexibility for ramp loading and taxi operation. We've also reaffirmed our premise that a wing tip to terminal structure clearance of 20 to 25 feet is adequate.

Blast fences are a requirement for specific instances, particularly during this interim. These are: to protect an adjoining carrier (we, too, adhere to a good neighbor policy), to separate adjacent ramp positions to permit simultaneous operations, to afford protection to fixed facilities or equipment not specifically designed for jet operation and in selected maintenance areas on a very limited basis, more to deflect sound.

Noise levels inside buildings of conventional construction to be no greater than with piston engine aircraft. In some instances, because of the character of the noise, it is even less objectionable. And kerosene fumes within the terminal can be a problem unless specific measures, where appropriate, are taken to prevent their entry.

Personal safety must be emphasized. Operators, airport authorities, everyone should do all possible to minimize the personal hazard when near an operating jet engine. During multiple engine operation and until people fully appreciate the hazards of suction, blast and noise energy, every precaution should be taken to eliminate or reduce, insofar as possible, all possibilities of personal hazard.

There is still time for designers to incorporate into terminals, the same degree of skill that was applied to the jet airplane to cater to airline operation and passenger convenience. Airport terminal complexes should include integrated passenger loading schemes which carry the terminal environment up to the airplane loading door. Effort should be directed to reducing walking distances and providing improvements in baggage claim. High speed access roads between cities and airports are just as necessary, especially when the larger and newer airport is located considerably beyond the suburbs.

And lastly, a comment regarding support equipment. Our philosophy was to keep everything required for ground support of the airplane on the ground and not to penalize the airplane with installed weight required for equipment needed only on the ground. This, we believe, has yielded better ground service because essentially more substantial, industrial type units can be utilized without the same degree of consideration for weight and size. Further, aircraft delays can be avoided by eliminating machinery aboard the airplane.

Ground support equipment must be matched properly to the three different jet airplanes we plan to operate. Accordingly, particular attention was devoted to the relationship between aircraft systems, ground support and ground handling. Important advantages were obtained by adjusting aircraft systems to implement support programming more feasibly and economically. It is significant that for the first time we found that aircraft system selection can be dependent in an important way on ground equipment cost and utility.

Aircraft designs were coordinated in such manner that ground handling techniques and support equipment could be standardized for all aircraft. Apparent results have been faster, more efficient ground service, substantial economy in equipment costs and improved service and comfort for the passenger.

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THE DEVELOPMENT OF DESIGN CRITERIA FOR WASHINGTON INTERNATIONAL AIRPORT TERMINAL FACILITIES

Richard M. Huber[1]*

Historically, Washington is the 4th largest commercial airline passenger generator. It is very close in number of passengers boarded to Los Angeles. Actually, 2 months of the present year has placed Washington Airport in the position of being the second busiest airport in the United States exceeded only by Chicago Midway. Even back in 1938 and 1940 the planners then developing what is now known as Washington International Airport could foresee the day when another airport would be needed. They studied a site at Camp Springs, Maryland, and World War II intervened. That site became Andrews Air Force Base. In 1948, airlines operations increasing by leaps and bounds, the CAA made a study which concluded that a second airport for the City of Washington would be needed in the immediate future. In 1950, Congress passed enabling legislation and in 1951 a site known as Burke was selected, but for various reasons had to be abandoned. For 6 years no progress was made until 1957 when Congress voted appropriations for a second airport with the stipulation that no funds were to be spent until the President had caused all available sites to be studied and the best site selected. The President delegated the responsibility for preparation of this study to Mr. Elwood R. Quesada, who then held the position of Special Assistant on aviation matters. Mr. Quesada selected as the consultant the Griner-Mattern Company to make the necessary investigations and prepare a report. On January 14, 1958 the selection of a site near Chantilly, Virginia was announced and the FAA was directed to have the airport operating in late 1960 or early 1961.

The firm of Ammann & Whitney, associated with Eero Saarinen & Associates, Burns & McDonnell, and Ellery Husted, were selected as the Architect-Engineer consultants in May of 1958 to prepare the engineering and architectural designs and supervise construction. We were faced with a problem of developing an airport for the future with particular emphasis on those facilities which would be compatible with the operational problems of jet aircraft.

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1. Architect-Engr., Project Manager, Washington International Airport, Chantilly, Va.

* Slides and motion picture were used to illustrate Mr. Huber's presentation.

In the United States there has never been an airport of this magnitude started from the very beginning with the intention of developing and constructing facilities for the next 5 years as well as preparing complete working drawings and plans for the airport up to the year 1975. The forecast of activity for this airport is based on a projected figure for the Washington-Baltimore area of 17 and 1/2 million annual passengers enplaning and deplaning; one hundred thousand tons annually of mail and cargo; 846,000 annual aircraft movements and 244 aircraft movements IFR per hour. Washington International Airport was forecast to have 396,000 annual movements of the 846,000 forecast for the area. Washington National Airport now is handling in excess of four and one-half million (4,500,000) passengers annually and is forecast to increase to 6 million passengers which the FAA considers as optimum capacity for that airport. This passenger capacity can only be reached by the introduction of large aircraft since the acceptance rate of the airport is only 32 aircraft per hour. When Washington International Airport is completed it is anticipated they will have 4,000,000 passengers by 1965; 6 to 7 million by 1970 and 8 to 10 million by 1975. In planning the development of the airport numerous factors had to be taken into consideration. First was the air traffic control capabilities which determined to a great extent the capacity of the airport. The ease of airport traffic control from both the controller's and pilots' viewpoints, as well as the effect this airport would have on the surrounding areas. In the site selection for this airport certain ground rules had been laid down. It would be no further than 30 miles from the center of town, nor should the driving time be in excess of 40 minutes. It was preferred that the distance be not in excess of 20 miles and preferably not more than 30 minutes driving time. There also had to be adequate highways, or the ability to provide adequate highways so that the trip to the airport did not become a burdensome chore. The site, of course, had to be large enough. Population had to be at a minimum to avoid disrupting communities. Community relations were an extremely important factor as they pertained to land patterns, existing and forecast, the displacement of community functions, the impact that a development such as this might have on local business and, of course, it had to be as nearly compatible as possible with regional plans for highways, industries and cultural aspects of the community.

Other factors were also taken into consideration such as the availability of utilities, rail facilities, and the characteristics of the site itself as they pertained to soils, drainage and topography. The result, after numerous sites were studied was the selection of one near Chantilly, Virginia.

The first job, of course, was to determine the best layout and after considerable study the Federal Aviation Administration selected parallel N-S runways 6700 feet apart and 11,500 feet long. These runways overlap by 50 per cent. There are also to be parallel W-N-W, E-S-E runways 10,000 feet long separated by 3,000 feet. After considerable study by the air traffic control centers, it was determined that 65% of all traffic would operate to the north with alternate take-offs to the NW.

The site at present consists of approximately 9,600 acres—one-third in Fairfax County and two-thirds in Loudoun County, Virginia. In order to maintain a good community relationship, the property line is a minimum of 2,000 feet laterally from the center line of any runway. The end of each runway is a mile and one-half from the property line. This enables us to have an airport which under the terms of FAA TSO-N-18, the aircraft will clear 150 feet by the time they reach the property line after take-off. A greenbelt is being

maintained or will be established where it is thin around the perimeter of the airport 1000 feet in depth. This is planned to help alleviate the noise problems which the jets tend to create. As part of the program, we are also designing 17 miles of access highway. This will be a four-lane divided highway with right-of-ways for 3 additional lanes in each direction in the future. Since the area of the airport is so vast, many local roads have been disrupted. To offset this condition a peripheral highway is being constructed around the airport. With a project of this size facing us, I am proud to announce that work started on the site in September of 1958 and the heavy grading started in October of 1958. Since we were selected as the architect-engineers last May we have been quite busy. It requires a minimum of a miracle a day to keep this project on schedule and I believe at this moment we are considerably ahead of what could be considered a normal schedule. To date, three contracts have been awarded totalling 19 million dollars. These covered clearing and grubbing, grading and drainage, and paving of certain of the runways. In grading alone in these contracts there are eleven and one-half million (11,500,000) cu. yds. of earth to be moved, of which well over 3 million have been moved to date.

In order to achieve the necessary results the contractor has assembled a vast array of equipment including several of the largest pieces of earth-moving equipment existing today. Among other things he has the world's largest excavator which is diesel electric powered like a locomotive and can move 100 cu. yds of earth at a bite. There are 14 miles of storm sewer pipe of which more than 3 miles have been installed to date. Paving will consist of 1,600,000 square yards which is equal to 118 miles of 24 foot highway. Incidentally, in order to make this an airport for the future we had to "design" our own airplane. We "blew up" a combined DC-8 and 707 aircraft by giving it a 20 foot greater wing span and 36 foot greater fuselage length. This hypothetical aircraft was assumed to weigh 500,000 lbs and have a dual tandem gear similar to a DC-8 or 707. After considerable study, portland cement concrete was chosen for the runways, taxiways and apron. In critical areas, that is, the ends of the runways and a strip 50' wide down the center of the runways, turn-offs, and taxiways will be 15" thick on a 9" stone base. In non-critical areas, the pavement will be 12" thick on a 9" stone base. The runways and taxiways will be provided with 25' wide bituminous shoulders which will be a 2" topping on a 4-1/2" rock base. In order to handle this large paving job, the contractor has installed at the central batch plant 3 nine cu. yd. mixers. With the equipment he has, he can pour one lane the length of a runway in four working days.

Lighting of the airport will be the most modern available. We will have high intensity lights on the edges of all runways as well as center line lights. At each end of each runway, provision is being made for the installation of the new "narrow gauge" lights. At this time, however, fixtures will be installed only in the ends of the runways that will be equipped with ILS. Provisions are being made, however, for the future installation of ILS systems on each end of each runway. The taxiways will be equipped with edge lights and the high-speed turnoffs will have both edge and centerline lights. This will require the installation of over 3600 light bases and 97 miles of underground duct.

One of the unique features of this airport are the bi-directional high speed turn offs. This is the first airport anywhere to be constructed using the results of the University of California tests conducted for the Air Modernization Board. These high speed turn-offs will enable an aircraft to leave the runway

at 60 miles per hour and turn on to the taxi-way at the same speed if necessary. Such operations will in effect tend to create more air space as the airplanes can be landed somewhat closer together than is possible on a conventional runway turn-off pattern. Many of the details of the terminal area have not been resolved although the work is progressing. A master plan has not been fully resolved to date but all that has been planned to date will be fully compatible with the final master plan.

Ample building areas will be provided which will accommodate hangars, overhaul facilities, general aviation and the other facilities normally found at an airport.

As the requirements for aircraft operation and handling were being considered, we did not overlook one of the major aspects of importance at a modern airport: the passenger. Many of us have felt for some time that the way passengers were handled at the new large modern airports approached being an insult to the dignity of the human race. In order to see exactly what happened to the passenger we made studies of his activities with particular emphasis on the walking distances involved.

These studies showed distance a passenger must travel from the time he parks his car or enters the terminal building until he can board his airplane. As an example, at a terminal with 29 gates, an interchange passenger might have to walk over 2300 feet at that airport. When you consider that WIA is being planned for a capacity of 100 gates, you can well see what the problem might be. At another major airport, the interchange passenger might have to walk a mile. Following the conventional planning of centralized and decentralized terminals, we plotted WIA on these two basis and came up with essentially the same distances that had been achieved at other airports. In order to keep a close eye on aviation's competitor, we also investigated Grand Central Station in New York and if it weren't for one commuter platform, the walking distance there would be considerably less than at most airports. We also studied the systems that are used to load the passenger on the aircraft. The first chart represents the conventional system of a terminal building, a finger and an open exposed area from the finger to the aircraft where the passenger may enjoy all the benefits of rain, snow, blast and noise.

Another system has been proposed called the aero-gang plank, which is an extension on the finger and bridges the gap from the finger to the aircraft. Neither of these systems appeared to solve the problem because the walking distance always remained the same.

In many European airports passengers are conveyed by means of a vehicle from the terminal to the aircraft but in almost every case the vehicle is not well suited to the job as it is still necessary for the passenger to walk from one level to another and he is still exposed at times to the elements. We studied this system and came up with a somewhat modified concept of the European method. That is, a vehicle which we have termed the mobile lounge to transport the passenger from the terminal building to the airplane. The passenger level of the mobile lounge is at the second floor level of the terminal building. It is a commodious vehicle approximately 15' wide and 60' long which will accommodate 80 people in comfort. This vehicle will operate somewhat similar to a ferry boat. That is, it never backs up. One end is adapted to meeting with the Terminal Building and the other end has a special pneumatic device for sealing the gap between the vehicle and the aircraft so the passenger is protected at all times.

Operationally the mobile lounge will originate at the terminal building, proceed out to the apron where the aircraft are parked adjacent to service units. Space on the apron is provided so that the massive aircraft I described as our design aircraft awhile ago can taxi in and out of position without being towed. This will reduce taxi time and distance considerably over that of any other scheme we have been able to evolve. Furthermore, to get back a moment to the walking distance you will note that with the mobile lounge the maximum walking distance will be a thousand feet for the interchange passenger, bettering even the walking distance which has been achieved at Grand Central.

A motion picture described the operation of the mobile lounge.

At this time detailed information on the Terminal Building cannot be released. Essentially though the building will be oblong with a finger to accommodate a few shorthaul aircraft and a certain number of helicopters. Within the next few months we will be able to release to the public information about the terminal building and how it will function. It will be a two-level operation with a roadway entrance on one level and the exist on another level.

The Mobile Lounges will operate from the opposite side of the building.

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DEVELOPMENT OF RIGID PAVEMENT DESIGN CRITERIA FOR MILITARY AIRFIELDS

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FOREWORD

Within the past eighteen years, the Corps of Engineers has designed and constructed some two and one-half billion dollars worth of military airfield pavement facilities. In order to reasonably assure that these pavements perform satisfactorily under the unprecedented loadings and traffic conditions imposed by military aircraft, the Chief of Engineers has invested more than ten million dollars in research and engineering investigations for development of valid design procedures for both rigid and flexible pavements. Since the military construction program is world-wide in scope, it has been necessary to consider extremely wide ranges of physical properties for both foundation and paving materials including the effects of seasonal frost and permafrost.

The rigid pavement design procedures developed in the investigational program have produced pavements with a proven record of adequacy from the standpoint of construction feasibility, structural capacity, surface smoothness and durability for support of such propeller-driven aircraft as the B-29 and B-36 and more recently for the B-47 and B-52 jet bomber aircraft. The trend toward growth in newly developed military aircraft has continually made obsolete even the most advanced pavement design concepts. Depending upon the ultimate outcome of the current competition between aircraft and missile weapons systems in our national defense planning, it is entirely possible that the saturation point in pavement load-carrying requirements has been reached. Certainly the gross loading of the present B-52, which is near one-half million pounds, will exceed that of any commercial aircraft in the foreseeable future. There remains the possibility, however, that heavier military aircraft than the B-52 will be required. Consequently, the Chief of Engineers is currently

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conducting an accelerated traffic test program for the heaviest aircraft gear loading that can be anticipated within the next 10 to 20 years. The current heavy-load studies are aimed at developing pavements which will permit rehabilitation of existing pavement systems or construction of entirely new facilities should the need arise.

There is considerable evidence that any future growth in military aircraft will produce loadings that will require greater conventional pavement thicknesses than it is practicable to build. The 25 and 27-inch thicknesses of nonreinforced concrete pavements required by the B-52 are extremely difficult to construct in such a way as to maintain the smoothness requirements and crack-free surfaces essential to the operation of these high performance planes. In the present testing program, serious consideration is being given to the less conventional pavement types such as multiple-layered systems and prestressed concrete.

While the commercial "jet age" airfield pavement designer will very likely face many problems and considerations beyond the scope of the rigid pavement design development investigations undertaken by the Corps of Engineers, there will be many phases of his work to which these studies will have immediate application and very often provide complete solutions.

Background

Shortly after the Corps of Engineers was assigned responsibility for the design and construction of military airfields in November 1940, two major problems developed which required immediate solution. The first was the advent of the so-called heavy bomber aircraft represented by the B-17 Flying Fortress and the B-24 Liberator. These aircraft had just gone into production and were designed to produce single-wheel main gear loadings of 35,000 pounds, with a maximum gross weight of 75,000 pounds. This loading was some 3 to 5 times greater than any loading highway or airfield pavement designers had dealt with previously. The second problem and one of equal importance was lack of a rational and valid design procedure by which either a rigid or a flexible-type pavement could be designed to carry these loadings.

As pointed out in reference (1), a simple, practical and uniform method of design for use in all parts of the world was essential. Certainly there was no shortage of design procedures. In the United States alone, practically every State Highway Department had developed and was using methods that invariably differed in some particular from those of any other state. Many of these design procedures had considerable merit but were related in concept to the locale in which they were to be applied and were often empirical and based entirely on experience and performance records of pavements in the particular area. Obviously, none of the procedures had been developed to give answers for the wheel loadings facing the Corps of Engineers in early 1941.

Again referring to reference (1), after a thorough study of all available design procedures, the Corps of Engineers embarked upon a pavement investigational program which would accomplish the following objectives: (a) Obviate the use of untried methods; (b) Insure adequately designed pavements; (c) Provide methods not subject to variation occasioned by arbitrary cost differentials of local competitive materials; (d) Avoid reductions in pavement thickness in

order to balance cost; and (e) Establish procedures that would readily lend themselves to further development through tests, investigations, and study of actual pavement behavior.

This paper will deal only with the design development studies related to rigid pavements and primarily with investigations related to pavement thickness requirements. Many of these studies undertaken and particularly those associated with loading and traffic conditions have had direct application to both the rigid and flexible pavement investigational programs. However, the Corps of Engineers flexible pavement development work has been well covered in the technical literature and is considered beyond the scope of the paper.

Investigational Program 1941 - 1950
Theoretical Concepts

It would be a misconception to assume from the foregoing that no rational or theoretical approach to rigid pavement design existed prior to 1941. As early as 1926 the late H. M. Westergaard after a long period of study, partly under the auspices of the Bureau of Public Roads, had developed methods for computing stresses in concrete pavements by theoretical analysis.(2) In this early work Westergaard treated the concrete slab of finite dimension as a thin plate, assumed a circular loaded area and a liquid subgrade. These equations were somewhat restrictive in that they were formulated to give the stress in the concrete either at the center of the loaded area (center slab loading) or at points a considerable distance from the loaded area. In 1939 Westergaard concluded that his basic equations which had been modified to some extent to conform to the results of the Arlington Road Tests of the Bureau of Public Roads were equally as applicable to the design of airfield pavements and aircraft loadings as to highway pavements.(3) Prior to the use of the very large aircraft tires with eliptical-shaped foot print area and the multiple-wheeled landing gear assemblies of modern aircraft little argument could be found with this conclusion.

It is interesting to note that Westergaard never presented a definite procedure for the determination of his "coefficient of subgrade reaction, k". He recognized that the modulus (which is expressed in pounds per square inch per inch of deflection or more simply as an expression of density, lbs/in.^{3}) would have considerable variation for a given set of conditions depending upon the size of the loaded area. It was concluded that so long as "the loads were limited to a particular type, that of a wheel load on top of a pavement, it was reasonable to assume that some constant value of the modulus, k, determined empirically, would lead to a sufficiently accurate analysis of the deflections and the stresses." This rather broad instruction later cause investigators a good deal of concern in establishing testing procedures, as might have been expected. Certainly the size characteristics of an automobile or truck tire on a 6-inch concrete paving slab in 1926 would be substantially different from those associated with the 265,000-pound B-52 main landing gear assembly loading on four large aircraft tires covering an area larger than 12 feet in its greatest dimension, and resting on a slab 27 inches in thickness.

In 1943 and 1949 Westergaard developed equations for multiple-wheeled gear configurations, with eliptical-shaped tire contact areas and for the critical corner and edge stresses in a slab.(4) In these later works, he made a "plausible estimate" of the correction necessary to bring his liquid subgrade

assumptions into agreement with results which would be expected if the subgrade were a "deep elastic solid". Even at this late date, however, Westergaard referred to the modulus of subgrade reaction as "an empirical makeshift" justifiable by "usable results". Again, when dealing with relatively light loads and pavement thicknesses in the range of 6 to 9 inches it is true that large variations in k value have little effect on the computed stresses. Unfortunately, this is not the case when dealing with the heavy loadings and pavement thicknesses required by military aircraft of today. Consequently either an accurate determination of k value or a healthy conservatism in arbitrary assignment is necessary to insure adequate pavement performance.

Correlation of Theory with Field Performance

In early 1941, the Corps of Engineers set out to check the validity of Westergaard's center slab loading theory by constructing a large number of individual 20 by 20-foot concrete slabs on a range of subgrade strengths and testing them to failure under static circular plate loadings and under the dynamic loading produced by dropping a loaded aircraft tire onto the pavement. These tests were conducted at Wright Field, Dayton, Ohio, and are commonly referred to as the Wright Field Slab Tests. The results of these tests are presented in detail in two Corps of Engineers technical reports(5,6) and have been referenced in numerous other publications in technical literature. It was in conjunction with these tests that the original work was accomplished for developing a standard test procedure for the measurement of the subgrade modulus k. The test slabs were instrumented with deflection and strain gages so that the failure loads could readily be related to the Westergaard theory. Through the entire range of increment loads leading to the development of the first structural break in the pavement slabs, a check was maintained on the volumetric displacement of the subgrade beneath the slab. From this determination the modulus of subgrade reaction could be established. A series of plate loading tests were made on each subgrade condition in order to determine the size of plate which would yield a k value that most closely checked the value obtained from the volumetric subgrade displacement measurements under the test slabs. Circular plates ranging in diameter from 12 to 72 inches were used in this study and almost without exception tests made with a 30-inch diameter plate gave results that were in close agreement with the subgrade displacement determination. As would be expected smaller plate sizes gave higher values and larger sizes gave smaller values. Thus was born the basic procedures for establishing a design k value with a 30-inch diameter plate bearing test that is still used in Corps of Engineer pavement design with only minor modification. A discussion of the development of the field bearing test procedure as applied to pavement design is contained in reference (7).

The principal conclusions derived from the slab test series were: (a) That the Westergaard equation accurately predicted the critical loading at which structural failure occurred under a center slab loading condition, and (b) That dynamic loadings produced no greater stresses in a concrete slab than equivalent static loadings.

Based upon these rather encouraging results the next step in the investigational program was to establish the type of loading which should govern the design of a pavement facility; static, dynamic, or repetitive traffic. A rather popular opinion shared by many engineers at the time was that the most

critical loading occurred at the point of touch-down in a landing operation. The violent "squeal" produced by aircraft tires at the point of touch-down may have had a great deal to do with this line of thinking.

Establishment of Design Loading Conditions

In an attempt to resolve this question a series of flight tests were conducted at Dayton Municipal Airport at Vandalia, Ohio in October 1941. These tests were conducted by the Air Corps with forces from the Corps of Engineers doing the ground work. A Martin B-26 Medium Bomber having an individual main gear loading of 15,000 pounds was used. The procedure was one of measuring the width of the tread markings left on the runway pavement after a series of the most severe landings the pilot could make without damaging the plane. Lime was placed on the pavement surface to more clearly define the tread markings. By correlating the measured width of tread at the point of touch-down with the width of the tire contact area obtained in the dynamic loading drop tests on the test slabs at Wright Field an accurate determination of the impact loading was possible.

The results of these tests where the aircraft was actually "flown into the ground" showed that the total load acting on the pavement at the point of touch-down ranged from 150 to 200 per cent of the static load. However, it was the pilot's opinion that such "hard" landings would be extremely rare (perhaps one in several hundred operations). Similar measurements made during a subsequent series of "normal" landings showed that the load at touch-down was only 40 to 60 per cent of the static load, thus tending to discount the high impact loading concept. If one considers that an aircraft has considerable speed and a resulting lift acting on the wing surfaces during landing operations, the latter finding is not surprising.

In more recent years, the significance of impact loadings during landing operations would not be great, even assuming a high percentage of "hard" landings. This may be explained by the fact that the landing weight of our heaviest jet bomber is seldom more than 60 to 70 per cent of maximum take-off weight for which the pavements are designed. Thus, a high order of impact during landing operation could occur without overstressing the pavements.

In continuing the study to establish the critical design loading condition, observations were made comparing the performance of equal strength pavements at various locations in an airfield pavement system at a number of airfields. It was found that the earliest signs of pavement distress invariably occurred in the areas of high taxi traffic concentration on the taxiways, aprons, and runway ends. This led to the conclusion that the repetitive traffic of slowly moving aircraft was in reality the most severe loading to which an airfield pavement was subjected. This finding tended to make the applicability of the Westergaard center slab loading equations questionable for airfield pavement design. An early series of traffic tests, wherein a vehicle carrying the equivalent of the static design loading on each of two wheels was towed over pavements at several installations, cast further doubt on the complete adequacy of the center load concept. These traffic tests were conducted in 1942 and 1943 on rigid pavements at McDill, Maxwell, Godman, Wright, Marietta, and Hamilton Army Airfields. Although the scope of the several testing programs was widely divergent, one of the primary conclusions drawn

in each case was that the center slab loading theory, without modification or safety factor was not sufficiently conservative for design purposes.

By 1943, there was a definite need for rigid airfield pavement design criteria and the Corps of Engineers published a criteria[8] based upon the Westergaard analysis for interior slab loading. Inasmuch as the Westergaard analysis was applicable only for computing stresses due to interior loadings, and since investigations, which had already been conducted indicated that stresses due to edge or corner loadings were higher, the published criteria contained a conservative safety factor plus requiring load transfer devices or thickened edges at all construction and expansion joints.

Accelerated Traffic Tests

In June 1943, the first of a series of full-scale accelerated traffic tests under completely controlled conditions were initiated at Lockbourne Army Airfield, Ohio. These tests, the results of which are shown in reference (9), were designed to permit a comprehensive evaluation of the many factors influencing rigid pavement design, and were placed under the direction of the Ohio River Division Laboratories in Cincinnati, Ohio, which has since been designated the Corps of Engineers Rigid Pavement Laboratory.

In retrospect, the objectives of the Lockbourne No. 1 Test Tract were very ambitious. The range of test loadings (20,000, 37,000, and 60,000 pounds on single wheels) was intended to be representative of the most severe military aircraft of that day and for several years to come. At the time, the B-17 and B-24 bombers were still the heaviest in active service and the B-29 which had been forecast to have a gross weight of 120,000 pounds was still fn the drawing board stage.

The test track itself consisted of sixty six individual pavement sections or test items ranging in thickness from 6 to 10 inches on various strength subgrades and various thickness and quality of base course, as well as a limited number of overlay and steel reinforced slab designs. All items were instrumented to permit deflection measurements at the interior, edge, and corner of the slabs under both stationary and moving loads.

Prior to applying traffic, it was necessary to establish the volume of traffic that needed to be considered. Based upon traffic frequency figures furnished by the Army Air Corps an estimate was made of the total number of operations of critical aircraft that would be expected in a 10-year period. Additionally, an investigation was made of the lateral distribution of aircraft traffic considering the natural tendency of aircraft to deviate from a single path on a runway or taxiway. After a large number of observations (both direct and using photographic techniques) it was established that for the aircraft of that day 75 per cent of all taxiway operations were so controlled as to confine the main landing gear wheels in a 25-foot path and were reasonably uniform within that width. Similar observations on runways showed that 75 per cent of the traffic occurred in approximately a 50-foot path. Assuming two operations (one take-off and one landing) occur on a runway for each operation on a taxiway the number of passages of an aircraft landing gear over any point on the pavement within the above boundaries would be essentially the same. (Although this general ratio of operation is still valid on modern military airfields, the weight of the landing aircraft is so much less than that of the take-off aircraft that an operational ratio of one to one is now assumed for

design purposes. The width of traffic path has also changed considerably for modern aircraft, being much more confined on taxiways than that shown above).

By correlating the number of aircraft operations expected on a given pavement facility with the lateral traffic distribution characteristics, a reasonable prediction can be made of the number of maximum stress repetitions to which a point in a pavement structure will be subjected. In such an exercise and for military airfields, only those aircraft operations occurring at or near maximum gross weight need be considered, since the traffic of lighter aircraft or that of the aircraft controlling the design when operating at substantially reduced weight, do not contribute greatly to pavement deterioration.

For the above correlation, traffic repetitions are converted into "coverages" by the Corps of Engineers. One coverage occurs when each point in the pavement surface has been transversed by a tire of the main gear. In 1943, 5,000 coverages was established as being representative of a 10 year plus pavement life. Naturally, the ratio between traffic operations and coverages will vary greatly depending upon the size and number of tires on a main gear. In this respect the military pavement designer has been fortunate until very recently because the larger aircraft with large tire multiple-wheel landing gear configurations have operated less frequently than the original single-wheel aircraft for which the traffic study was made. Consequently, the 5,000 coverage level remained reasonably valid for many years.

In the early tests at Lockbourne, only 3,000 traffic coverages were applied to the bulk of the test sections in order to facilitate rapid completion. However, an empirical correlation was applied to the test results so that design criteria could be established on the 5,000 coverage basis.

The basic conclusions developed from the results of the Lockbourne No. 1 Test Track are summarized below:

a. Stresses produced in a pavement slab by either traffic or static loadings are more severe when the loading is applied at the corners and edges of a slab than when applied at the center.
b. The Westergaard edge load equations (developed in 1943) were valid for a single loading condition but an additional "design" factor had to be applied to properly account for stress repetitions (fatigue), temperature gradients and other unknown variables.
c. Service behavior indicated that slab failure (progressive cracking after the development of an initial crack) occurred much more rapidly in slabs on low strength subgrades than in those on high strength subgrades.
d. Expansion joints were a definite source of weakness unless load transverse devices were employed.
e. Small slab sizes (10 feet x 10 feet) proved less desirable than larger slabs (12.5 feet x 20 feet) from the standpoint of developing surface roughness under traffic.
f. Steel reinforcing delayed visible initial cracking and prolonged useful life after cracking.
g. Crack patterns in the base slab of a rigid overlay pavement are quickly reflected into the overlay slab under condition of overload.

While the results of the Lockbourne No. 1 Test Track were not "earth shaking", they did establish a sound basis for applying the Westergaard

equation which had been developed for determining edge stresses. Based upon these findings, revised rigid pavement design criteria was developed using the Westergaard analysis for edge stresses and assuming (developed from the Lockbourne tests) that properly designed joints would provide a 25 per cent load transfer to the adjacent slab. A "design" factor of 1.3 was included in the criteria to compensate for load repetitions of 5,000 coverages. This revised design criteria was published in reference (10).

A resumé of the Corps of Engineers test program of full-scale concrete pavements up to 1944 is contained in reference (11).

Between 1944 and 1948 three other major accelerated traffic testing programs were accomplished by the Rigid Pavement Laboratory at the Lockbroune Test Site. Lockbourne No. 2 Experimental Mat was perhaps the most extensive airfield pavement testing program ever undertaken based strictly on the number of pavement sections tested and evaluated. The Lockbourne No. 2 testing program initiated in 1944 was prompted by the development of the B-36 aircraft which, as originally designed, had a gross weight of more than 300,000 pounds and produced a single-wheel loading of 150,000 pounds. This loading represented a growth of some 250 per cent over the gear loading that had been considered an upper limit less than one year previously. Results of these tests are contained in reference (12).

The test sections incorporated some 120 individual pavement sections ranging in thickness from 9 to 24 inches, and included non-reinforced and reinforced pavements, multiple-layered overlay systems with and without bond-breaking courses, a wide range of subgrade and base course conditions, and a large number of joint design configurations and slab sizes. Briefly, the results of these tests established the accuracy of the Corps' design curves for this extremely high loading.

Several airfields were designed and constructed for the 150,000-pound single-wheel loading (Wright-Patterson, Loring, Travis, and Carswell Air Force Bases) in anticipation of the B-36 operation. However, only the prototype model of the B-36 used the large single-wheel main gear, the later production models converting to a four-wheel twin-tandem assembly. A limited test program (Lockbourne No. 2 Modification) on pavement thicknesses of 12, 15, and 20 inches was conducted for this multiple-wheel gear configuration and the results again supported the ability of the Westergaard equations to properly predict stresses in rigid pavements under multiple-wheel landing gear loadings. Results of the Lockbourne No. 2 Modification tests are shown in reference (13) and a discussion of these test results was given in reference (14). A few of the more pertinent findings are as follows:

a. Bond-breaking courses between pavement layers even as thin as asphalt prime coats, greatly reduce the useful life of a rigid overlay system.
b. Reinforcing steel in rigid pavements permit a nominal reduction in the required non-reinforced slab thickness. However, the price of steel at the time of the tests made it extremely doubtful that the reinforced design would be economical. (As a general rule this is a valid conclusion today, although special conditions often make the use of reinforcing steel mandatory).
c. Based upon the performance of the test items in Lockbourne traffic tests and upon instrumentation measurements of deflections and strains, the following listing of joint types from strongest to weakest can be made:

(1) Doweled contraction joint
(2) Doweled construction joint
(3) Keyed construction joint with tie bars
(4) Contraction joint
(5) Keyed construction joint
(6) Doweled expansion joint
(7) Free edge expansion joint

d. There was no apparent advantage to using structural shapes in preference to conventional round dowels for load transfer at joints in thick concrete pavements.

The increased loading of the B-29 (60,000-pound twin wheel gear) and the B-36 (150,000-pound twin-tandem wheel gear) necessitated the need for design criteria for strengthening existing rigid pavements. Several rigid overlay on rigid pavement test items had been included in the Lockbourne No. 2 Experimental Mat and from the performance of these test items an empirical design criteria had been developed and was published in reference (10). In 1946 a limited investigation (Lockbourne No. 3 pavement overlay investigation) was conducted to study the performance of non-rigid overlays (asphaltic concrete and base courses) on rigid pavements. The test track consisted of nine test items having varying thicknesses of non-rigid overlay on an 8-inch rigid base pavement. The test items were trafficked with a 60,000-pound twin wheel gear load and indicated that the use of a flexible material was a feasible method for strengthening existing rigid pavements. Based upon these limited tests a tentative design criteria for non-rigid overlay on rigid pavement was developed and published in reference (15).

By 1948, the Corps of Engineers had developed rigid pavement design criteria with a proven record of adequacy for the traffic of single and multiple-wheel landing gear assemblies, for loadings as high as the 150,000-pound single wheel and for tire inflation pressures of up to 200 psi. Small-scale model study techniques had been developed from which theoretical predictions could be checked and many unusual or unique concepts could be evaluated and design procedures developed under controlled conditions. The model studies have served in recent years to supplement and greatly reduce the scope of the full-scale traffic test sections. A discussion of the applicability of a small-scale model for studying concrete pavements is given in reference (16). Results of pertinent studies of concrete pavements with the small-scale model is given in references (17,18,19). A constant check has been made on the actual performance of pavements at a large number of airfields through a program of condition surveys of existing pavements. The information gathered by the condition survey teams which include structural performance, traffic records (loadings and frequencies), physical property data and weather conditions has led to several empirical changes to the theoretical design concepts through the years.

In 1950 the United States Air Force and the Army Corps of Engineers jointly established a unified loading criteria for the design of future military airfield pavements to be used by the Air Force. These were established as 25,000 pounds on a single wheel having a tire contact area of 100 square inches for jet fighter-type aircraft and designated as Light-Load Pavements. A design loading for Heavy-Load Pavements was established at 100,000 pounds on a twin-wheel gear configuration, 37-1/2-inch center to center spacing and an individual tire contact area of 267 square inches. The Heavy-Load criteria

was based on what was considered to be the maximum weight that would occur on one main landing gear of the forthcoming B-47 jet bomber.

Neither the Corps of Engineers nor the Department of the Air Force foresaw any difficulty in developing criteria for the design of plain rigid pavements for these standardized loadings since concepts developed for the heavier propeller-driven aircraft prior to 1950 appeared to be applicable. Therefore, design criteria were published in 1951[15] and construction of the modern multi-mission Air Force Bases was initiated. Unfortunately, the problem wasn't that simple.

Investigational Program 1951 - 1959
Overlay Pavement Studies

The only design criteria in doubt in 1951 was that for the design of overlay pavements to strengthen existing pavements. These criteria had been developed empirically from a very limited number of full-scale test items and it was felt that additional tests were needed to firm up this criteria. Therefore, during 1951-1954, two full-scale overlay pavement test tracts were constructed and tested in the Sharonville General Services Administration Depot at Sharonville, Ohio. The test site at Lockbourne had to be abandoned due to the expansion of the airfield facilities. The first of these test tracks (Sharonville No. 1) was a study of non-rigid overlays on rigid pavements and consisted of 16 test items; 3 of which were all-asphaltic concrete overlays on rigid pavements and 11 were flexible overlays (3 items of asphaltic concrete with waterbound macadam base and 8 items of asphaltic concrete with asphalt macadam base course) on rigid pavements. Two plain rigid test items were included in the track to validate the 100,000-pound design criteria, and to provide a basis with which to compare the performance of the overlay test items. The test track was trafficked with a 100,000-pound twin wheel gear load during 1951 and 1952. An analysis of the test results indicated that the tentative criteria for non-rigid overlay design published in 1951 was unconservative in some respects and the criteria was revised and published in reference (20). However, the results of the Sharonville No. 1 tests still left much to be desired, especially regarding the design of flexible overlays (asphaltic concrete and base course) on rigid pavements.

The second overlay test track (Sharonville No. 2) was constructed in 1953 and contained 29 test items; 8 of which were rigid overlay on rigid pavement; 4 were rigid overlay on flexible pavement; 11 were all-asphaltic concrete overlays on rigid pavement; and 6 were flexible overlays (asphaltic concrete and base course) on rigid pavement. This track was also trafficked using a 100,000-pound twin wheel gear loading. An analysis of the results of these tests indicated that the empirical criteria for the design of rigid overlays on rigid pavements developed from the Lockbourne Pavement Overlay Studies were conservative for partially bonded (no bond breaking course between the pavements) rigid overlays on rigid pavements and the empirical criteria was revised and published in reference (20). Results of the tests on the non-rigid overlay test items, in general, substantiated those from the Sharonville No. 1 tests; however, it was found that the tentative criteria published in 1954 was conservative in some instances and unconservative in others. Based upon these findings, all information regarding non-rigid overlay tests was reanalyzed to find a method which would satisfactorily explain the performance

of all test items. From this analysis, which is described in references (21), (22), a criteria was established and published in reference (23) for the design of non-rigid type overlays on rigid pavements. This criteria is, with only minor modifications having been made, still valid for the design of non-rigid overlay pavements today.

High Strength Foundations

During the period 1951-1955, the condition survey program, which was initiated in 1946, was beginning to yield significant findings insofar as pavement performance under actual aircraft traffic was concerned. It could be shown conclusively that rigid pavements constructed on high strength foundations were performing much better than the design criteria would indicate. An analysis of the condition survey results led to the following two conclusions which seemed to explain this better than anticipated performance. First, the modulus of subgrade reaction, k, was higher than the maximum value allowed in design, and secondly, although pavements cracked during traffic, the cracking was not detrimental to aircraft operations since the high strength foundation prevented faulting of the broken slabs and spalling along the cracks. Up until this time the maximum modulus of subgrade reaction, k, allowed for design was 300 lbs/cu. in. since the validity of the plate bearing test procedure for measuring higher values was questionable. A series of plate bearing tests were performed on high strength foundations to either prove the existing procedures or to develop a valid test procedure. These tests proved that the existing test procedures were adequate if a correction were applied to compensate for bending of the steel plates under load. It was found that the necessary correction was dependent only upon the foundation strength and was irrespective of the type of material. The test procedures were revised to include the correction for bending of the plates and maximum k values of up to 500 lbs/cu. in. were allowed in the design criteria published in 1954. The required pavement thickness for k values in excess of 200 lbs/cu. in. were also reduced to allow a nominal amount of cracking of the slabs in order to realize the maximum benefits of the high strength foundations.

Channelized Traffic

In February 1954, a condition survey conducted at Lake Charles Air Force Base, Louisiana, showed distress occurring in the center lane after about 2 years of B-47 aircraft traffic. The distress was in the form of longitudinal cracking at or near the center of the middle slab in a 75-foot wide taxiway and ran continuously for several hundred feet. A rather intensive investigation was conducted which indicated that the pavement and foundation strengths were equal to or exceeded the values used for design. In investigating the cause of the distress it was finally concluded that the probable cause was due to a channelization of the traffic which was producing coverages at a much faster rate than was assumed in the design.(24) Further distress of this type was soon evidenced at other airfields that were being subjected to B-47 aircraft traffic.

These signs of distress indicated that there was a definite need to reinvestigate the design loadings and, more importantly, the ground operational characteristics of the B-47 aircraft. A series of field studies(25) were conducted to

determine the traffic pattern of aircraft during ground operations and a series of meetings were held with Air Force developmental and operational personnel to learn more of the aircraft loadings and the ground handling techniques that were being employed. The field studies showed conclusively that the steerable gears and the painted taxi strips gave the pilot a much finer control and that pavements in certain areas were being subjected to as many coverages with the B-47 aircraft in from one to two years as the same amount of traffic had produced in 10 years with the distribution that had been experienced with previous aircraft. These studies also indicated there was a "porpoising" action with the bicycle-geared aircraft that produced an impact loading on the pavements exceeding the static loading of the gear.

After an analysis of the information developed through these field studies and meetings, it was evident that revised heavy load design criteria was needed. The studies indicated that for a 10-year pavement life the coverage level would reach approximately 30,000 in certain areas, while in other areas where traffic was more distributed, the coverage level would reach only 5,000. It was also evident that the impact loading caused by "porpoising" of the aircraft must be taken into account in the design, while in still other instances the studies indicated that the pavement thickness could be reduced due to the majority of traffic being with an aircraft loading less than the maximum gross weight. Using this information, design criteria were established for the B-47 aircraft based upon a two wing (90 aircraft) operation per field. These heavy load criteria, which were put into effect in May 1955, were as follows:

a. Design Loading: 100,000 pounds on a twin-wheel landing gear, twin-wheel spacing of 37-1/2-inches center to center, and a 267-square inch contact area for each wheel (190 psi inflation pressure).
b. Impact Loading: Equal to 15 per cent of the design gear loading.
c. Design Coverages: In order to distinguish the coverage levels and loading conditions that occurred on the various pavement facilities, the pavements were divided into types of traffic areas in accordance with the anticipated coverage level and loading. The traffic areas were designated as "A", "B", and "C" and the design coverages and loading conditions were established as follows:

   (1) Type "A" Traffic Area—30,000 coverages at the design gear load plus the impact loading. Pavement facilities classed as Type "A" traffic areas were the primary taxiways leading from the parking apron to the ends of the runways and the first 500 feet of each end of the runway.
   (2) Type "B" Traffic Area—5,000 coverages at the design gear load plus the impact loading. Pavement facilities classed as Type "B" traffic areas were secondary taxiways, the second 500 feet at each runway end, warm-up aprons, hangar aprons, wash racks, etc.
   (3) Type "C" Traffic Area—Same design as a Type "B" traffic area, except that the required pavement thickness was reduced by 10 per cent to compensate for reduced aircraft loading during operations on these pavements. Pavement facilities classed as Type "C" traffic areas were runway interiors (portions between the 1,000-foot runway ends), parking aprons and calibration hardstands.

Inasmuch as past investigations had been based upon a maximum coverage level of 5,000, the increase to a design coverage level of 30,000 necessitated

extrapolation of existing information to arrive at pavement thickness criteria. It was felt that the Westergaard analysis supplemented by the small-scale model studies were still valid; however, the fatigue characteristics of the pavement under these high number of stress repetitions were not known, since previous full-scale accelerated test tracks had never been subjected to more than 5,000 coverages. Therefore, full-scale test tracks were constructed at the Sharonville Test Site and subjected to 30,000 coverages of the 100,000-pound twin wheel gear loading to validate the above design criteria and to establish the fatigue characteristics of rigid pavements at these higher coverage levels. Two test tracks, designated as the Sharonville Channelized Test Tracks, were constructed; one on a low strength subgrade and one on a high strength subgrade.(26) Each track contained both plain concrete and steel reinforced concrete test items and were subjected to traffic in such a manner as to simulate the actual aircraft traffic on a taxiway pavement. The results of these full-scale accelerated traffic tests, a resume of which are contained in reference (27), validated the extrapolation that was made to arrive at the above described design criteria and no further revisions in the thickness requirements were necessary.

Accelerated Traffic Channelized Test Tracks

The increased thicknesses (up to 22 inches) required for the 100,000-pound loading at the higher number of coverages being applied, caused increased attention to be focused on methods for reducing these thicknesses through steel reinforcement or prestressing of the pavements. An empirical reinforced rigid pavement design criteria was developed and published in reference (28), based upon the results of the traffic tests on the reinforced rigid pavement test items in the Channelized Test Tracks and upon previous tests on reinforced rigid pavement test items at the Lockbourne Test Site. In essence this criteria allowed for a reduction in required pavement thickness depending upon the amount of steel reinforcement used. Although it was realized that generally a reinforced rigid pavement would be more costly than an equivalent strength non-reinforced rigid pavement, there was a definite need for such a design criteria to produce some way in which certain pavement thicknesses could be reduced to meet surface grade requirements. This was brought about, primarily, by the requirements for different thicknesses in the various traffic areas and, when strengthening an existing pavement, it was impossible to meet surface grade requirements without either removing and replacing large areas of pavements or over-designing certain areas.

Prestressed Pavement Studies

Investigations of prestressed concrete pavements, which had been initiated in 1953, were stepped up since this type construction appeared to be the best means for reducing the required pavement thickness. Up until 1955, most of the work with prestressed concrete pavements had consisted of a review of theoretical approaches to design by the Preload Engineers, Inc. of Arlington, Virginia (references (29), (30), (31), (32)) under contract with the Rigid Pavement Laboratory and a series of laboratory model studies to determine such variables as friction between the slab and the subgrade; buckling characteristics; methods of prestressing; concrete creep under stress; etc. A

comprehensive review of French and British procedures in the design of prestressed pavements was made which was presented at the Highway Research Board Meeting in 1957.(33) From these preliminary studies, tentative design concepts were developed for prestressed pavements(34) and in 1956, a 4-inch prestressed concrete overlay mat was constructed on a 6-inch plain rigid base pavement at the Sharonville Test Site.(35)

The overlay mat served two purposes: First, to study the feasibility of full-scale prestressing; and second, provide some information of the performance under traffic. The prestressed overlay mat was fully instrumented to measure strains and deflections under both static and dynamic loading and the mat was trafficked with twin-wheel gear loadings of 45, 60, 75, and 100 kips. The analysis of the test results from the overlay mat were complex and could, by no means, be considered conclusive; however, the tests did indicate that construction of prestressed concrete pavements was entirely feasible and the performance under traffic indicated that these type pavements could become economically competitive with non-reinforced rigid pavements due to the drastic reductions in thickness that could be made. A full-scale, 100-foot long by 5-foot wide, prestressed slab was constructed in 1956 with which friction measurements between the slab and foundation were made and the slab is to be used for further buckling tests. In the meantime a series of small-scale model studies were initiated to study prestressed concrete pavements.(36) It was found that the small-scale models were readily adaptable for making studies of this type and a variety of gear configurations could be studied cheaply and quickly. The small-scale model studies were concluded in 1958 and from an analysis of the test results, a design criteria was developed which agreed very well with other theoretical analyses. The design criteria developed by the model studies lacked one very important factor however; that being the fatigue characteristics of prestressed concrete pavements. This could only be determined from dynamic tests such as those performed by full-scale traffic testing and hence a test track for prestressed concrete pavements was planned and constructed at the Sharonville Test Site in 1957. A resume of the prestressed concrete pavement investigation was given in a paper, reference (37), at the World Conference on Prestressed Concrete, held in San Francisco, California in 1957.

Revised Heavy-Load Design Criteria

At about the time the B-47 pavement design criteria were firmed up, information was received on the forthcoming B-52 aircraft and indications were that this aircraft would produce even greater pavement stresses than the B-47 aircraft. When the first models of the B-52 became operational, the aircraft had a gross weight of 460,000 pounds and a bicycle-type arrangement of the main landing gears similar to the B-47 aircraft. The gear loading was 240,000 pounds and was carried by a twin-twin wheel arrangement with a twin-wheel spacing 37-inches center to center and a spacing of 62 inches between the two interior wheels. An analysis of the load-stress characteristics using both the Westergaard analysis and the small-scale model studies indicated that the 240,000 pounds on this gear would produce higher stresses than the current design loading of 100,000 pounds on twin wheels. Remembering the problems concerning the ground operational characteristics of the B-47 aircraft, studies were conducted to determine these characteristics with the B-52 aircraft;

however, since few B-52 aircraft were in operation, these studies were not conclusive. Revised heavy load design criteria were established and published in June 1956 for a design loading of 240,000 pounds on the twin-twin wheel landing gear and using the impact factor of 15 per cent of the design gear loading and the same design coverages for the Types "A", "B", and "C" traffic areas as had been used for the B-47 criteria. These criteria again had to be established from an extrapolation of existing data, since these loadings exceeded any full-scale testing that had been accomplished. The extrapolation was; however, believed to be valid since the previous extrapolation for the B-47 criteria had proven to be correct.

During 1956 further field studies of the ground operational characteristics of the B-52 aircraft were made and showed that the degree of "wander" of the aircraft was about the same as for the B-47 aircraft. This meant that the design coverage level for taxiways should be the same as had been used for the B-47; however, an analysis of the traffic on the runways showed that there was an overlapping of coverages due to the twin-twin wheels and that for the same amount of traffic the coverages would be about three times as high for the B-52 as it was for the B-47 aircraft. On this basis the design coverages for Types "B", and "C" traffic areas should be 15,000 instead of the 5,000 used for the June 1956 criteria; however, no change in criteria was made immediately since there were indications that the design loading might be increased.

In June 1957, the Air Force indicated that a new model of the B-52 aircraft was soon to become operational and that modifications to the aircraft had increased the gross weight to 498,000 pounds. This produced a gear loading of 265,000 pounds on the twin-twin wheel gear, making it more severe than the loading of 240,000 pounds then being used for pavement design. To further complicate the situation, the Air Force announced a new dispersal concept for the B-52 aircraft which would reduce the number of aircraft stationed at an airfield from the two wing (90 aircraft) concept to a one squadron (15 aircraft) concept. A re-examination of the coverages that would be produced with the dispersal concept, and considering the new relationship between traffic and coverages on runway interiors, it was indicated that the design coverage level could be reduced to 3,000 for the Type "A" traffic areas and 1,500 for the other traffic areas. However, the Air Force indicated that each airfield should have the capability of handling one wing (45 aircraft) and the design coverage levels were established accordingly.

During the field studies conducted in 1954 - 1955 for the B-47 aircraft, and in 1956 for the B-52 aircraft, it was noted that practically 100 per cent of all operations with both aircraft occurred within the center 100-foot width of the runway. From these findings, it was concluded that the outside edges of the runway could be designed for a much lower coverage level than the 5,000 being used; however, since the width of B-47 runways was only 200 feet, it was felt that to decrease the thickness of the outside 50 feet on each side of the runway was an unnecessary refinement in the design and construction. In addition, the Air Force still desired to maintain the capability of making take-offs in echelon which would require full strength pavements for the full width. With the coming of the B-52 aircraft, the runway widths were increased to 300 feet and the traffic studies still indicated that practically 100 per cent of the traffic was within the center 100-foot width. Since a reduction in the thickness of the outside 100 feet on each side of the runway would result in a material savings, and there was little likelihood of making take-offs in echelon

with the B-52 aircraft, another type of traffic area, Type "D", was introduced for the outside edges of B-52 runways and the design coverage level was established at 200.

The condition survey program indicated that the Type "C" traffic areas were performing far better than anticipated under B-47 aircraft and indications were that the same would be true for B-52 aircraft. The reason for the good performance was not immediately evident; however, it was apparent that either the design coverage level or the design loading was higher than needed. Since the traffic studies had been used to set the coverage level on runways, the logical conclusion was that the pavements were not being subjected to the loadings assumed in design. It was known that the 10 per cent reduction in thickness for the runway interior pavements was illogical since this represented a load reduction of from 13 to 23 per cent depending upon the landing gear configuration and the properties of the pavement and foundation. However, the reduction was a carry-over from previous criteria and was used for the lack of better information in regard to the actual loadings. A change in the design criteria for runway interiors appeared to be in order to place this reduction in thickness on a more rational basis by establishing a uniform average reduction in load based upon the effects of high speeds and wind lift acting on the aircraft. The reduction was established at a constant 25 per cent of the design load and was applied to all Type "C" traffic areas. Although the same reasoning of high speeds and wing lift did not apply to such other Type "C" traffic areas as aprons and secondary taxiways, the performance of these pavements appeared to be very similar to the runway interiors; thus, the same load reduction was applied.

Considering the heavier loading, the dispersal concept, thinning up of runway edges, and the constant load reduction for Type "C" traffic areas, revised heavy-load design criteria for B-52 pavements was established and published in February 1958.(38) These revised criteria were as follows:

a. Design Loading: 265,000 pounds on a twin-twin wheel gear, 37-inches center to center spacing between twin wheels and 62-inches center to center spacing of the interior wheels, and a 267-square inch contact area per tire. (tire inflation pressure 250 psi).
b. Impact Loading: 15 per cent of the design gear load.
c. Design Coverages:
   (1) Type "A" traffic areas: 10,000 coverages at maximum design gear loading plus the impact loading.
   (2) Type "B" traffic areas: 5,000 coverages at maximum design gear loading plus the impact loading.
   (3) Type "C" traffic areas: 5,000 coverages at 75 per cent of the design gear loading plus the impact loading.
   (4) Type "D" traffic areas: 200 coverages at 75 per cent of the design gear loading plus the impact loading.
   (5) The above criteria is believed adequate for a 10-year pavement life for a one wing (45 aircraft) operation; a 20-year pavement life for a combination one wing and one squadron (average 25 aircraft full time) operation; or a 20+ year pavement life for a one squadron operation (15 aircraft).

The above criteria again had to be extrapolated since full-scale traffic tests had not been performed at gear loadings greater than 100,000 pounds on twin wheels. A test track was considered; however, information received from the

Air Force in 1956 and again in 1957 indicated that future aircraft (possibly within 5 years) would produce gear loadings of 325,000 pounds and would in all probability be carried by a twin-tandem wheel landing gear. Therefore, it was decided that a test track should be considered for a gear loading of 325 kip, from which criteria could be interpolated to validate the 265,000-pound twin-twin wheel design loading. A test track at the 325 kip loading would then provide criteria for any aircraft in the foreseeable future (10 to 15 years).

Accelerated Traffic Tests with Future Loadings

In 1957 test tracks were designed and constructed for accelerated traffic testing of a 325,000-pound twin-tandem wheel gear loading. Extrapolation of existing design criteria indicated that plain concrete thickness of up to 32 inches might be needed and it was immediately evident that construction of such thicknesses would not only be costly but would require modifications to existing construction methods in order to place such thicknesses. It was also apparent that there would be an immediate need for criteria to strength existing pavements to carry these heavier loads. As a result of these considerations, a total of four test tracks were designed and constructed, each approximately 500-feet long by 50-feet wide and several test items were incorporated to study the feasibility of pavement sections that had not previously been considered for airfield pavements, due to their excessive cost when compared to plain concrete. A brief description of the pavement sections in these test tracks, which are referred to as the Sharonville Heavy-Load Test Tracks, follows:

a. Track A—Test items of plain concrete, rigid overlay non-bonded to a rigid base pavement, rigid overlay bonded to a rigid base pavement, and a multiple-layered test item composed of a rigid overlay on as asphaltic concrete placed on a rigid base pavement. The high bonded rigid overlay item was included as a pilot study to determine the feasibility of using the acid etch and wash-grout method, developed by the Portland Cement Association, to bond an overlay to an existing pavement and thereby reducing the required thickness of the overlay. The multiple-layered test item was also included as a pilot study since it was evident that there would be a need for criteria to design a rigid overlay to strengthen an existing rigid pavement which previously had been strengthened with a non-rigid (asphaltic concrete) overlay.
b. Track B—Test items of plain concrete on lean mix (2 bags/cu. yd.) concrete base courses. The primary purpose of this test track was to determine whether there were any structural or economical benefits to providing a high strength foundation for rigid pavements. This type construction has been used with apparent success in several foreign countries.
c. Track C—Test items of steel reinforced concrete on plain concrete. The test track was provided to develop design criteria for reinforced rigid overlays and to validate the reinforced rigid pavement design criteria, which had been developed from the results of the Lockbourne studies and Sharonville Channelized Test Tracks previously described.
d. Prestressed Test Tracks—Test items of 9-inch concrete with various combinations of longitudinal and transverse prestressing and longitudinal prestressing with steel reinforcement in the transverse direction.

The heavy-load test tracks were designed and constructed prior to the change in design coverage level for the aircraft dispersal concept, hence, the tracks are designed for coverage levels ranging from 5,000 to 30,000+. Each of the test tracks is well instrumented to measure concrete strains and pavement deflections under both static and dynamic loadings and thermocouples are provided throughout the depths of the thicker test items to measure concrete temperatures. Pavement separation gages are provided between the overlay and base pavements to determine the amount of separation, if any, that occurs due to traffic, temperature, etc. Other measurements that are made include the load transfer obtained by doweled longitudinal construction joints, joint openings and closures due to temperature changes, continual surface profiles and cross sections, and continuous observations of pavement performance under traffic.

Construction of the test tracks was completed in late 1957 and traffic testing was commenced in the spring of 1958. Instrumentation tests have been made on each test track at loadings of 100, 175, 250, and 325 kip, with the exception of Track C and the prestressed track on which the maximum load to date has been 275 and 265 kip, respectively. Approximately 10,000 coverages of the 325 kip load has been applied to Track A and approximately 2,000 coverages of a 275 kip load has been applied to a portion of Track C. As yet, insufficient traffic has been applied to draw significant conclusions as to the thickness requirements; however, it does appear that the extrapolation of information required for the design of the tracks will be approximately correct.

SUMMATION

Since 1951, the rigid pavement investigational program has been primarily pointed toward providing valid design criteria for the heavy-load pavements since the gross weights of the bomber aircraft have increased rapidly. Only very minor revisions have been required, insofar as pavement thickness criteria is concerned, for the light-load pavements since the growth in weights of the fighter-type aircraft has been relatively small during this period. In addition to the development of the light and heavy-load pavement design criteria, rigid pavement design curves have been prepared for practically every gear configuration on existing military aircraft. In all, there are approximately 17 different configurations of aircraft main gears consisting of single-wheel, twin-wheel, single-tandem-wheel, twin-tandem-wheel, twin-twin-wheel, and dual-twin-tandem-wheel groupings with a variety of wheel spacings and tire contact areas. However, practically all military airfield pavements today are designed for either the light-load or heavy-load criteria. Other designs are only used for very special conditions.

The paper thus far has dealt primarily with the development of pavement thickness criteria. Needless to say other problems have developed in regard to rigid pavement design and construction which have necessitated studies and investigations. The advent of the jet age in the late 1940's and early 1950's created many problems, not associated with thickness requirements, such as jet fuel spillage, heat and blast, requirements for smoother pavements with less grade changes, and the need for debris free pavements. The spillage of jet fuel during refueling operations or during engine run-ups softened and deteriorated the conventional joint sealing materials that had been used and a

jet fuel resistant sealing material had to be developed. Heat and blast from the jet and rocket motors were found to be of such intensity, with certain aircraft, that it caused deterioration of the concrete surface. An extensive investigation has been performed to measure the pavement temperatures created by the exhaust of jet aircraft and heat resistant materials have been developed which can be bonded to the surface of concrete pavements in the critical areas. It was evident that debris on the pavement surface created a hazard to jet aircraft operation, since the foreign materials could be pulled into the engine by the intake airstream and could cause extensive damage and even complete destruction of the engine. This meant that pavement spalling and raveling which could be tolerated to a certain degree with propeller-driven aircraft could be disastrous to jet aircraft operation. The higher take-off and landing speeds along with the inherent instability of the bicycle-type landing geared aircraft necessitated increased smoothness requirements and both fewer grade changes and less abrupt grade changes to prevent pitching and rolling of the aircraft during ground operations. The thicker pavements required for the heavier aircraft introduced many construction problems and have necessitated many changes in construction techniques. More rigid specifications and inspection during construction have been required in order to provide the type pavements necessary for the aircraft today.

Although all of the problems in pavement design and construction have by no means been solved, it is felt that great strides have been made in the past 18 years. It is evident, however, that we cannot continue to simply provide thicker and thicker pavements as aircraft loads increase. The present Sharonville Heavy-Load Test Tracks, which have concrete thicknesses up to 32 inches, have indicated that it will be extremely difficult to build non-reinforced rigid pavements in such a way as to provide the required smoothness and crack-free pavements that are required by the present and future high performance aircraft. There are strong indications that modifications in joint designs will be needed to prevent spalling along the joints in thicker pavements. These, along with many other associated problems, have led the Corps of Engineers to give serious consideration to less conventional pavement construction, such as steel reinforced rigid pavements and prestressed concrete pavements. The non-conventional pavement types, which in the past have always been considered to be uneconomical, may soon prove to not only be more economical but essential for satisfactory aircraft operation.

The Corps of Engineers' pavement investigational program, especially during the past 10 years, has proven the necessity for the pavement designer and the aircraft designer working together. It is absolutely essential that the pavement design engineer know not only the aircraft load and gear configuration, but he must also know the ground operational characteristics of the aircraft. It is equally important that the aircraft designer know the mechanics of pavement design if he is to intelligently select the gear configuration that will best distribute the load of the aircraft to the pavement. The following gives a cursory check list of essential aircraft information that is needed for the development of pavement thickness design criteria:

a. Aircraft Loading: The factors that must be considered when speaking of aircraft loading are many and varied. For example, it is not sufficient to know only the maximum gross weight of the aircraft without also knowing the range of gross weights that might be expected during

the operation of the aircraft. For military aircraft, the gross weight varies depending upon the operational mission. These missions generally are classed as transition training, operational training, full-scale target mission training and actual combat missions, with each mission representing a different operational gross weight. Although pavement designs are generally based upon the operations at the maximum gross weight of the aircraft, these other operations and weights must be considered.

b. Landing Gear Configuration: Information must be obtained on the number, arrangement and spacing of wheels; the distribution of weight on each main and auxiliary gear; and the arrangement of the main gears on the aircraft.

c. Tire Pressure and Contact Area: The size of the tire, the normal vertical deflection of the tire, and the standard tire contact area for a complete range of loadings must be determined.

d. Traffic Pattern: This involves a study of the normal flow of traffic. That is, determinations must be made of the number of aircraft and at what loading these aircraft use each pavement feature.

e. Traffic Distribution: Determinations must be made of the lateral distribution of traffic on each pavement since this determines the number of times that a pavement is subjected to load. Traffic is normally distributed over a wider area on a runway, for instance, than on a taxiway. Naturally, if all aircraft traffic is funneled into a narrow line (channelized), the pavement in that area is subjected to many more stress repetitions than is a pavement where the traffic is distributed over a wider area.

f. Traffic Frequency: A determination must be made of the number of traffic cycles (combination of landings and take-offs) that will occur at the airfield.

In closing, it is desired to re-emphasize that although considerable work has been accomplished in the development of adequate design criteria for military airfield pavements, there is a definite need for improved criteria particularly for new types of pavements that will reduce the required thicknesses for both current and future aircraft. Speculation indicates that future aircraft may reach a gross weight of one million pounds and if such loads to materialize, pavement design problems will increase accordingly.

The commercial "jet age" is just now getting under way and while the commercial aircraft gross weights may never reach those of the military aircraft, it is safe to assume that they will "grow" in both size and weights from those being used today. Gear configurations will also vary and the traffic volume, which is already higher than on military airfields, will probably increase as pavement layouts are improved. The civil airfield pavement designer will undoubtedly be confronted with many problems that the Corps of Engineers' has faced over the past 10 years. Additionally he is quite likely to face many problems beyond the scope of the Corps' rigid pavement investigations. It is hoped, however, that the foregoing discussions will provide assistance and guidance in either situation.

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32. "Typical Designs of a Prestressed Airfield Pavement—Part III", prepared by Preload Engineers, Inc., Arlington, Virginia for the Corps of Engineers Rigid Pavement Laboratory, Mariemont, Ohio, July 1954.

33. P. L. Melville, "Review of French and British Procedures in the Design of Prestressed Pavements", Highway Research Board Proceedings, 1957.

34. "Tentative Concepts for the Design of Prestressed Concrete Airfield Pavements", March 1958, prepared by the Corps of Engineers, Rigid Pavement Laboratory, Mariemont, Ohio.

35. "Design and Construction Report, Prestressed Concrete Overlay Mat and Buckling Slabs, Sharonville, Ohio", Technical Report No. 4-10, November 1958, prepared by the Corps of Engineers, Rigid Pavement Laboratory, Mariemont, Ohio.

36. Paul F. Carlton and Ruth M. Behrmann, "Model Studies of Prestressed Rigid Pavements for Airfields". Highway Research Board Proceedings, 1957.

37. F. M. Mellinger, "Prestressed Concrete Airfield Pavements". Presented at the World Conference on Prestressed Concrete held in San Francisco, California, 1957.

38. Engineering and Design Manual, EM 1110-45-302, "Airfield Pavement Design—Rigid Pavements", 3 February 1958, published by the Department of the Army, Corps of Engineers, Office of the Chief of Engineers.

Journal of the
AIR TRANSPORT DIVISION
Proceedings of the American Society of Civil Engineers

PRESTRESSED CONCRETE PAVEMENTS

Eric. C. Molke,*[1] F. ASCE

We normally design a rigid pavement with the general assumptions for an elastic beam or slab on elastic foundation. The basic principles were first applied more than 70 years ago for the design of railroad ties supported on stone ballast.

Westergaard, more recently has transformed the solution for the moments in the linear beam to the distribution of moments caused by wheel loads along the surface of a pavement slab.

The left half of Figure 1 illustrates the classic solution for deflecting and bending moments in the linear beam on elastic foundation. It is assumed that the foundation acts on the beam, like a system of elastic springs, but also that the beam behaves elastically perfect. The bending moment is positive with its maximum under the load and oscilates rapidly to zero in a damped wave, causing small negative moments before the load is absorbed completely by the elastic ground support. The relation of maximum positive to maximum negative moment is about 5 to 1. The distance from the load to the point of zero moment (point of inflection on the displacement curve) is a measure of that portion of the ground which takes an active part in supporting the load. If this distance is small, soil pressure under the load will be high; but bending moments in the slab will be low, as the slab will have little work to do, only spreading the load over a small distance.

Note in the formula of Figure 1, that this distance and consequently the resulting bending moments will be greater with greater stiffness EI of the beam and also greater with poorer soil, that is one that has a lower modulus of subgrade reaction. The isometric view in the right half of Figure 1 describes the dished deflected surface when a pavement is loaded. The circular bent portion of the slab acts like a shield protecting the ground from an abrupt destruction by the wheel load. A unit element is also shown in order to illustrate the protective action of radial and tangential moments in the dished slab. The distribution of the radial and tangential moments is shown below.

Note: Discussion open until December 1, 1959. To extend the closing date one month, a written request must be filed with the Executive Secretary, ASCE. Paper 2119 is part of the copyrighted Journal of the Air Transport Division, Proceedings of the American Society of Civil Engineers, Vol. 85, No. AT 3, July, 1959.

* Summers, Munninger & Molke, Cons. Engrs., Albany, New York.

1. Slides were used to illustrate Mr. Molke's presentation.

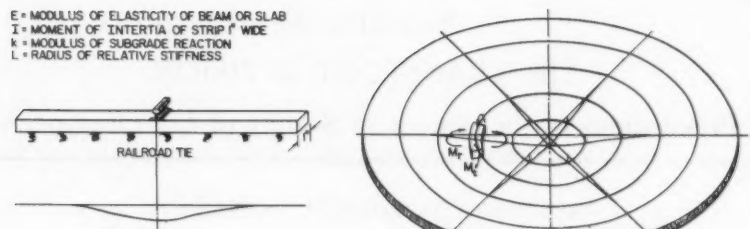

E = MODULUS OF ELASTICITY OF BEAM OR SLAB
I = MOMENT OF INTERTIA OF STRIP 1" WIDE
k = MODULUS OF SUBGRADE REACTION
L = RADIUS OF RELATIVE STIFFNESS
RAILROAD TIE
BEAM DEFLECTION
BENDING MOMENT
BENDING IN AN ELASTIC BEAM
PAVEMENT DEFLECTION
M_r RADIAL MOMENTS
M_t TANGENTIAL MOMENTS
BENDING IN AN ELASTIC SLAB

FIG. 1 - COMPARISON OF BENDING IN AN ELASTIC BEAM ON ELASTIC FOUNDATION WITH BENDING IN AN ELASTIC PAVEMENT SLAB ON ELASTIC FOUNDATION.

Again we can point out the distance to the point of zero radial moment (the point of inflection). Roughly this distance is referred to as the radius of relative stiffness. The greater the stiffness of the slab EI, the greater will be this radius and consequently also the protective bending moments in the slab; the better the soil value K the smaller will be the protective shielding action of the slab. As can be expected, greater slab stiffness or poorer soil value will cause greater shielding value.

The above described conventional classic design procedure are based on a perfect elastic behavior of the beam or pavement slab, the shape of the deflection curves being assumed continuous, as it would be before formation of cracks. Indeed no cracking of the bottom surface should be allowed for plain concrete pavements and a sufficient factor of safety (better called "impact factor") should be provided to prevent or postpone the formation of cracks in the bottom.

We know, however, from experience that minute cracks will eventually form in the bottom of a pavement which will in the course of time and under repeated traffic loading, work themselves to the top and finally cause the destruction of a pavement.

Small hair cracks occuring under load in the bottom of a pavement slab, will cause a re-distribution of bending moments. This is illustrated on elastic supports in Figure 2, for the simple case of a beam. All conclusions from this example apply also to the more complex case of the action in a slab support, extending in all directions.

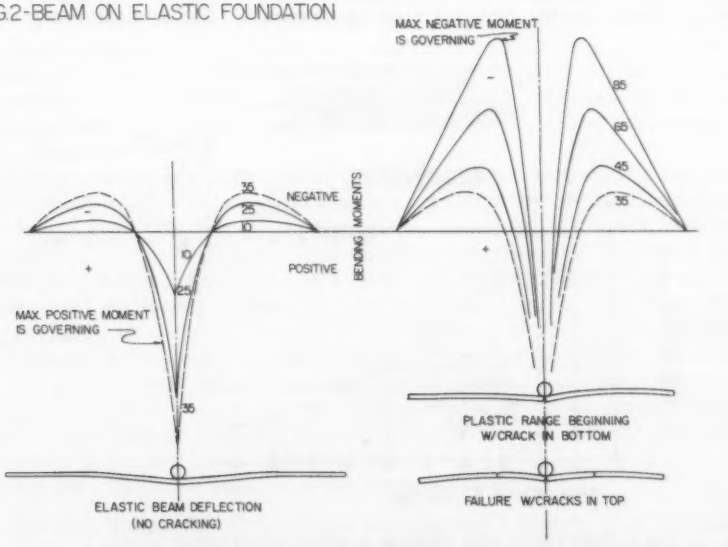
The left side of the figure represents the bending moments in a beam on elastic supports with gradually increasing load, as it will occur before the formation of any cracks that is in the so called "Elastic Range." It can be noted that with gradually increasing load, bending moments and deflection will increase proportionally up to the point marked 35, which represents the critical load under which cracking due to the maximum positive moment will occur in the bottom surface.

At this critical point the "Plastic Range" begins, which is illustrated in Figure 2 at the right side of the illustration. This bending phase is called "plastic" because cracks permit a certain yielding in the shape of the deflection curve, which instead of being smooth as at the left in Figure 2, is now becoming slightly angular. In a material less brittle than concrete, such as for instance with steel, similar yielding of the shape could occur without actual cracking. However, when this plastic phase is reached, even the best materials will loose some of their elastic qualities and will not return to their original shape after passage of the load.

As can be noted in the right half of Figure 2, there is a tremendous reservoir of carrying capacity in a beam on elastic supports after it has first cracked at the end of the elastic range. Before cracking, most of the load was distributed to the ground by a shielding action of the pavement with positive moments directly under the load.

In the plastic range the load is carried much farther outward by ever increasing negative moments. When the negative moment in Figure 2 reached the level of the maximum positive moment where the first cracks in Figure 2 have been indicated, another series of cracks will occur in top leading to final destruction of the beam or pavement. It should be noted that the load capacity

FIG.2-BEAM ON ELASTIC FOUNDATION



in the plastic range is almost three times as large as in the elastic range.

It is evident that we could not exploit the extra carrying capacity of the plastic range when dealing with a brittle pavement material like concrete. Even with a tougher material like steel, it would be dangerous to design for the plastic range on account of the permanent deformations with plastic yielding.

A prestressed concrete slab will, however, permit the formation of slight hair cracks in the bottom under the passing load, so essential to obtain the beneficial redistribution of moments in the plastic range. After passage of the load the prestress will harmlessly close the cracks and re-establish the original level surface of the pavement.

This in essence is the principal reason for the increased carrying capacity of a prestressed concrete pavement.

The increase in carrying capacity has been illustrated in Figure 2 from actual test results using strain gauge measurements on small models of prestressed beams on elastic foundation.* The conclusion drawn from such two dimensional beam tests also proves to be correct for the application to the three dimensional pavements on elastic foundation.

It should be noted that on ordinary structures, prestressing is generally used to produce stresses opposite to the ones expected under final loads, so that prestress and final load stress would cancel out each other. This principle cannot be applied with a pavement, where moving loads produce an ever changing pattern of stresses which cannot be provided for, except for the simple fact that prestress merely would add to the tensile strength of concrete, the latter being the basic criteria for pavement design. Knowing the behavior of bending in the plastic range permits, however, a much better evaluation of the advantages from prestressing a pavement.

The diagram in Figure 3 indicates, strikingly, how action in the plastic range will decrease the critical bending moments. Horizontally, is plotted

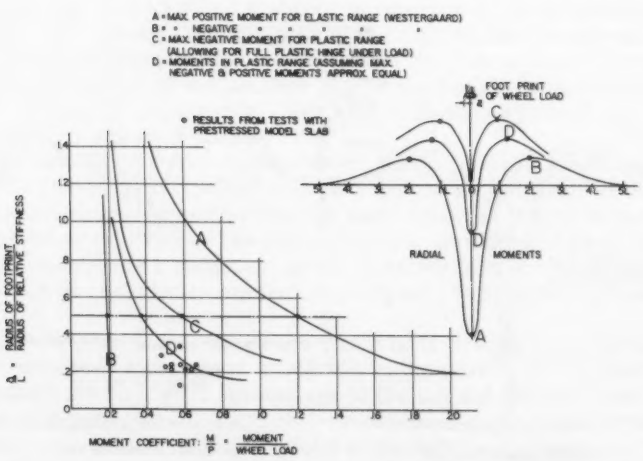

A = MAX. POSITIVE MOMENT FOR ELASTIC RANGE (WESTERGAARD)
B = " NEGATIVE " " " " "
C = MAX. NEGATIVE MOMENT FOR PLASTIC RANGE (ALLOWING FOR FULL PLASTIC HINGE UNDER LOAD)
D = MOMENTS IN PLASTIC RANGE (ASSUMING MAX. NEGATIVE & POSITIVE MOMENTS APPROX. EQUAL)
FOOT PRINT OF WHEEL LOAD
RESULTS FROM TESTS WITH PRESTRESSED MODEL SLAB
RADIAL MOMENTS
L = RADIUS OF RELATIVE STIFFNESS
MOMENT COEFFICIENT: M/P = MOMENT / WHEEL LOAD

FIG 3 - COEFFICIENTS FOR MAXIMUM MOMENTS IN PAVEMENT SLABS. ELASTIC AND PLASTIC RANGE

*see note at end of paper.

the dimensionless coefficient: Moment per unit width over wheel load. Vertically, is plotted also a dimensionless coefficient, that is: Average radius of foot print of wheel load, divided by the radius of relative stiffness of the pavement. (referred to in Figure 2).

Curves "A" and "B" are for the maximum positive and negative bending moment values in the elastic range, as indicated schematically at right by the lower curve for radial bending moments.

Curves "C" in the diagram applies to point C of the upper curve at right which is drawn with the assumption of a full plastic hinge under the wheel, reducing the moments there to zero.

Curve "D" in the diagram applies to the two points D along the remaining moment curve at right. This moment line was drawn with the assumption of such a plastic moment release directly under the wheel, which would reduce the maximum positive moment to about the value of the maximum negative moment. Points indicated by small circles near curve "D" indicates moments at failure in the plastic range on small prestressed model slabs.*

Prestressing, besides increasing the carrying capacity of a concrete pavement, has still another perhaps greater advantage. It will make it possible to increase the distance between pavement joints.

When depending only on the tensile strength of the concrete, as we do with conventional plain concrete pavements, we must provide joints about 25 feet apart so that no tensile strength of the concrete must be dissipated for the prevention of cracks. Cracks may form by ground friction, caused by contraction due to shrinkage or temperature. Bending due to secondary moments such as from the temperature gradient within the pavement or from slight differences in the ground support might also cause cracking unless frequent joints were provided. Most of all, the arrangement of joints themselves, with their intersecting corners are the cause of further cracking.

The multitude of joints in a conventional pavement will be the first cause of its disintegration. Even if it were possible to provide economically joints of a strength equalling the interior of a panel, they would still be a tremendous handicap to a pavement, if they permit entry of water into the subgrade.

With the use of jet planes, any desintegration of the joints becomes particularly dangerous.

There are types of prestressed pavements which can be made for any length without joints. It is also possible to arrange them with expansion joints at say 1000' spacing or farther apart. However, with such extremely large joint spacing, temperature and shrinkage stresses do become a great problem also with prestressed slabs, because the friction between sub-soil and pavement will greatly resist the shortening and expanding action of a long pavement. It appears, that it is uneconomical to arrange expansion joints more than about 500' apart. With such large spacing it becomes possible to allow for a better type expansion joint, employing proper edge protection and bridging provisions, such as sliding plates, finger joints or expanding rubber bellows. It becomes, however, imperative to reduce the sub-grade friction to a minimum to permit freer sliding action.

At present, three methods of prestressing are used.

a. Jacking the pavement against non-yielding abutments at either end and locking the pavement in this contracted condition. There are no expansion joints with this method.

*see note at end of paper

b. Post tensioning, that is leaving holes or conduits in the concrete, within which prestressing wires or cables are pulled taut by anchoring them against the ends of the slab after the concrete has hardened. Then the wires are stretched and the concrete is shortened at the same time. In this stage of strain the free space in the conduits is pressure grouted making a permanent bond between the compressed concrete slab and the tensioned steel units.

c. Pretensioning, that is stretching cables or wires between temporary abutments, casting the pavement slab around the stressed steel units and cutting their anchorage at the end, when the concrete has hardened. The concrete only becomes compressed or prestressed, when the steel ends are cut loose from the abutments.

Of these three methods of prestressing, only post tensioning has so far been practically employed in the U. S.

The most outstanding application is now being installed by the U. S. Army Engineers at Biggs Airforce Base, El Paso, Texas, for a runway, 75' wide and 1500' long.

The runway is separated by expansion joints into section 500' long. The pavement is cast in three ribbons each 25' wide so that conventional paving machinery could be used. The specifications required a concrete prestress of 300 psi in the longitudinal and 175 psi in the transverse direction and permitted to bid any of the now conventional prestressing methods.

A friction reducing sand layer was covered with a plastic sheet over which the 9" thick pavement was cast. The side forms were 25' apart and pipe

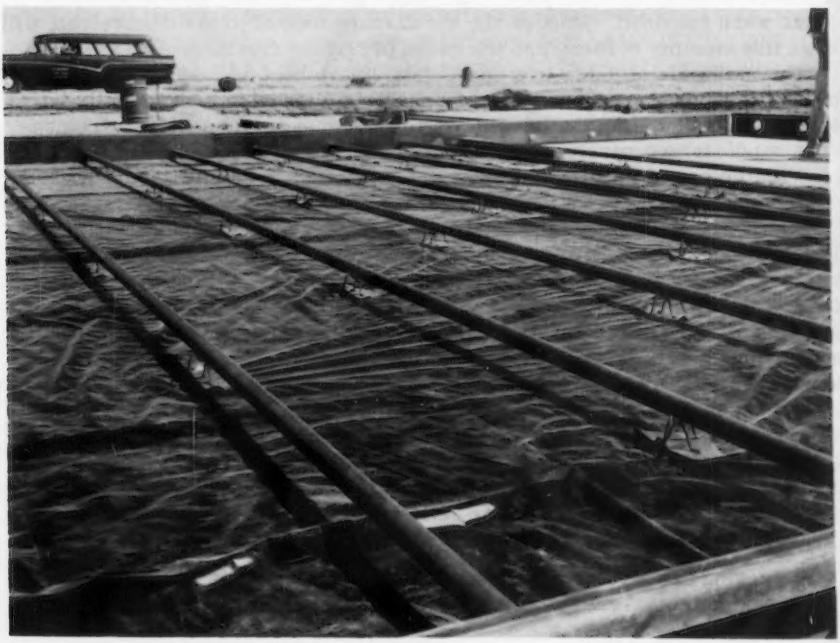


Figure 4

conduits supported on steel chairs thru which the transverse prestressing wire will be fed after all three 25' wide strips are cast, side by side.

The 500' long longitudinal prestressing units consist each of 12 wires sliding in a flexible conduit so that they can be stressed. The units are straightened by a preliminary tensile force applied with a long handled wrench as illustrated.

Transverse and longitudinal units are wired together securely before placing the concrete. Along a transverse stressing unit straddled by the legs of one of the steel setters, a series of projecting grout nipples are provided in the longitudinal units to allow the injection of pressure grout to fill the hollow spaces between the stretched wires in the 500' long conduits.

Concrete was placed by conventional machinery; even internal vibration can be applied, in spite of the presence of the prestressing units.

Stressing of the wires is done by hydraulic jacks, in the very same manner as done on building and bridge work and does not offer any particular difficulty, since the friction between wires and conduits is exceptionally low with the straight runs.

This paper merely intended to convey the basic principles for prestressed concrete pavements. Much could be added in regard to the possibilities in application.

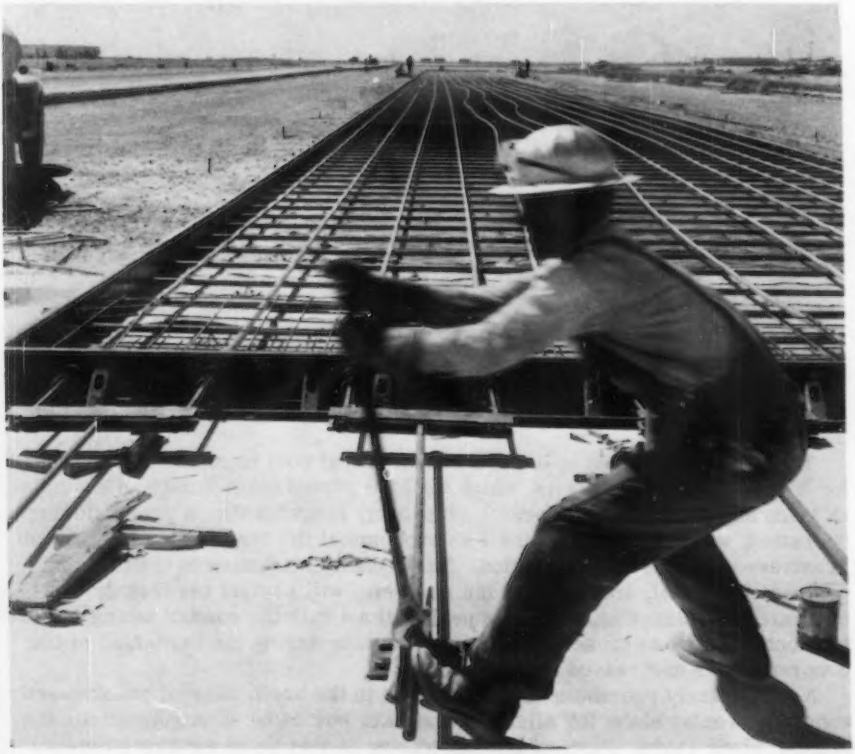


Figure 5

Figure 6

We must realize that only because concrete is such a cheap material it becomes attractive to rely on its small tensile strength, when designing conventional pavements. Strength for strength, we would not be able to achieve economy by merely substituting some of the concrete thickness with prestressing steel. We should, therefore, admit that a new prestressed pavement might be higher in first costs, at least at this time, when we are still inclined to be cautious and are over-designing and over-specifying this new medium.

There is good reason to believe that the usual post tensioning operation for longer runway pavements, which we have copied from European examples, is more expensive and less practical in many respects than a pretensioning operation, which has proven itself so economical in other fields of American prestressed concrete construction. Particularly attractive is the fact that pretensioned steel, embedded in the concrete, will protect the freshly cast concrete from cracking, while the perforations with the conduit tubing in post tensioned slabs can cause preliminary cracking during the hardening of the concrete in its unstressed stage.

A particularly promising field should be in the application of prestressed concrete overlay slabs for airfields that have now to be strengthened for the heavier plane loads. Particularly promising should be an application over existing flexible asphalt pavements, since a prestressed overlay gives high

Figure 7

protection with lesser thickness and thus is sufficiently elastic to leave some supporting action to do for the old pavement underneath.

The possibilities with prestressed concrete pavements seem to be tremendous and we can be sure that careful engineering, together with free competition between the various systems, will prove its advantages and economy.

*The model tests referred to have been carried out at the Corps of Engineers, Ohio River Division Laboratories in Cincinnati, Ohio, Mr. F. M. Mellinger, Director.

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Journal of the
AIR TRANSPORT DIVISION
Proceedings of the American Society of Civil Engineers

EFFECTS OF JET FUEL SPILLAGE AND BLAST ON PAVEMENTS

H. J. Lichtefeld*[1]

The new turbine-powered aircraft are now landing and taking off from several civil airports of the country and as time goes on the number will increase. Much has been said and written[1,2,3] about the pavement design problems associated with the effects of jet fuel spillage and heat and blast on airport pavements created by the operation of the turbine-powered aircraft. Much attention has been directed to these problems. Reports of damage have come from all sections. Frequently these reports have been misinterpreted due to incomplete data and lack of knowledge of operating procedures.

We in the Federal Aviation Agency have followed very closely the work of the interested and concerned segments of the Department of Defense relative to this problem. We have studied their operational techniques and analyzed their results, all of which have been of substantial benefit in coping with this problem for civil jet aircraft operations. It has been necessary to modify and interpret certain aspects of the related military findings and apply them to the civil operations in consideration of revisions to engine and aircraft characteristics previously published.[1,2,3] This paper therefore will review the pertinent factors having a bearing on this problem and their probable effect on civil airports.

Heat and Blast Effects

The critical factor with respect to the effects of heat and blast on the pavement is the combination of maximum temperature and velocity generated behind the jet engine and transmitted to the pavement surface. The temperature on the pavement surface is governed by:

1. The temperature and velocity of the gases at the jet orifices.
2. The height of engine nozzle above pavement.
3. Duration of the exposure of the pavement to the exhaust gases.

Note: Discussion open until December 1, 1959. To extend the closing date one month, a written request must be filed with the Executive Secretary, ASCE. Paper 2120 is part of the copyrighted Journal of the Air Transport Division, Proceedings of the American Society of Civil Engineers, Vol. 85, No. AT 3, July, 1959.

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1. Slides were used to illustrate Mr. Lichtefeld's presentation.

4. The deviation of the engine tailpipe from the horizontal.

Figure 1 is a plot of test results of thrust versus surface temperatures generated by operating inboard (No. 2 engine) and outboard (No. 1 engine) JT3C-6 engines. The tests were conducted by Boeing Aircraft Company on the 707 aircraft under the following conditions:

1. Engines equipped with sound suppressors and thrust reversers, both of which have reducing effects on temperature.
2. Deviation of the engine from the horizontal was 2^{o}.
3. Height of inboard engine nozzle center line above ground was 57 inches; outboard engine was 80 inches.

The maximum surface temperature was approximately 220^{o}F for the No. 2 engine at a point 35 feet aft of the inboard engine. The maximum surface

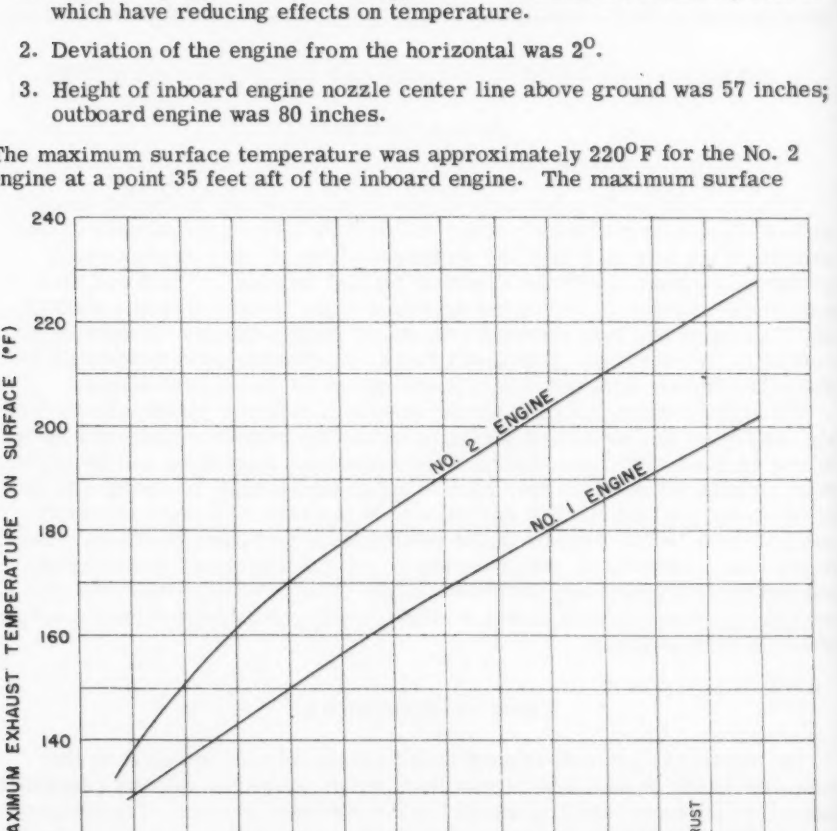

FIG. 1 EXHAUST TEMPERATURES AT SURFACE

temperature recorded for the outboard engine was approximately 200°F at a point 55 feet aft of the outboard engine.

The temperature difference on the pavement surface for the inboard and outboard engines is in agreement with previously reported data that decreased height of tailpipe above ground with constant angle of inclination increases the surface temperature.(5) The above indicated height of inboard engine tailpipe center line is for maximum taxiing load (248,000 pounds), and is some 7 inches lower than the height for operating weight empty (120,000 pounds). Variations in height of this order will have no material effect on the surface temperature since a 23-inch height difference between inboard and outboard engines resulted in only a 20° differential in surface temperature. The 2° deviation of the engine from the horizontal does not vary appreciably during actual operations, except at higher rolling speeds associated with takeoff. For the latter condition, any increased heat due to an increase in the engine inclination will have negligible effects on the pavement since its application will be practically instantaneous.

Figure 2 represents a calculated temperature survey of the flame pattern of a JT3C-6 engine at takeoff power for standard sea level and static conditions. Applying two governing factors under which the tests in Figure 1 were conducted - 2° inclination and a center line tailpipe height of 57 inches above the ground - to the flame survey in Figure 2, there results an indicated surface temperature of approximately 185°. This is about 35° less than that observed by actual measurements in Figure 1. Actual measurements are preferred; however, the above analysis may be made to give an indication as to what may be anticipated from civil turbine-powered aircraft operations.

In Figure 3 is presented similar data for a later version of the Boeing 707 with a JT4A-3 engine delivering more than 15,000 thrust pounds. It will be noted that the indicated temperature at the pavement surface is 225° for this engine under the same governing factors as were used in Figure 2.

Figure 4 presents the temperature survey for a CJ-805-21 Aft Fan engine to be used on the Convair 600 Jet Liner. The thrust of this engine approximates that for the engine shown in Figure 3. The inboard engine of this aircraft has a center line tailpipe height above the pavement of 56.5 inches with a minus 4.6° deviation from the horizontal. The plot of these data shows a maximum pavement temperature of about 225°. The aft fan of this engine produces cooler exhaust temperatures. The central 150° and 200° temperature cones of the exhaust gas are approximately 6 feet and 8 feet in diameter and extend to 34 feet and 38 feet, respectively, behind the tailpipe; for the JT4A-3 (Figure 3) the cone diameters are 8 feet and 12 feet and extend 65 feet and 105 feet, respectively, behind the tailpipe. This reduction of high temperature cones is accompanied by secondary cones of a larger diameter for a relatively shorter distance.

In considering the calculated temperature surveys of the flame patterns, it was assumed that ambient temperatures would have little influence.(5) Thermal energy dissipates when (1) there is volume and pressure change, and (2) when there is heat loss due to the temperature gradient. The high temperatures behind the nozzle would not be materially affected by changes in the ambient temperature with respect to its effect on the pavement. Additionally, changes in ambient temperature are of no consequence in the outer reaches of the temperature cones of less than 150° since that temperature range has no affect on the problem at hand. The analysis is further complicated by the absorption capacity of pavement due to color coupled with the jet blast

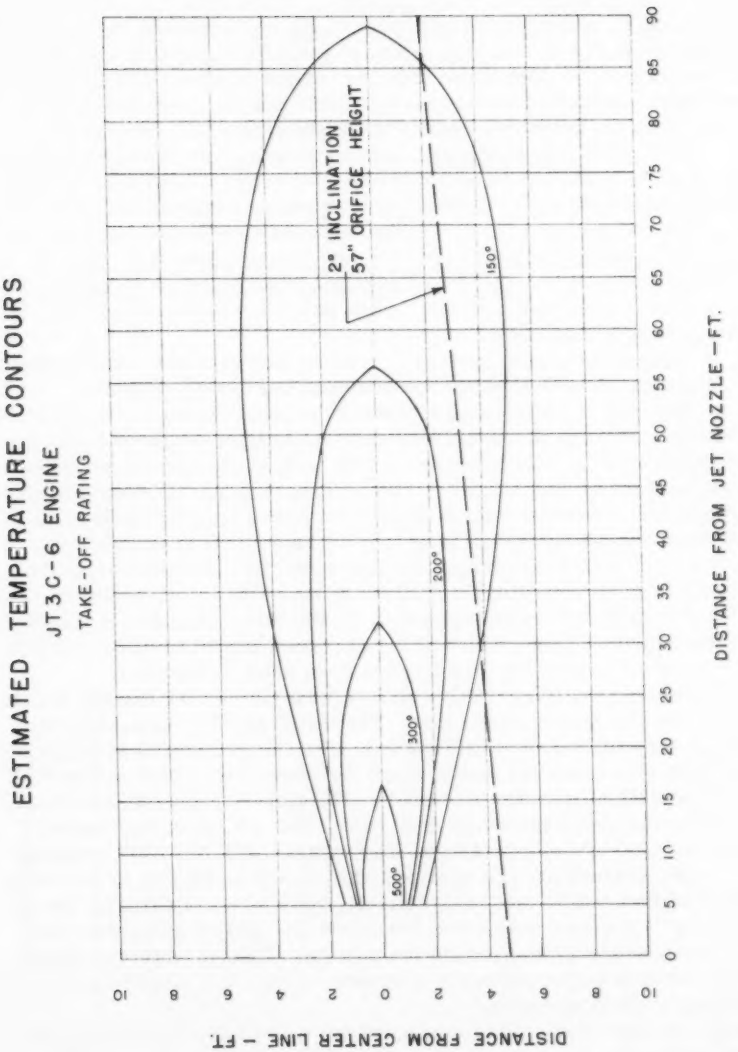
ESTIMATED TEMPERATURE CONTOURS
JT3C-6 ENGINE
TAKE-OFF RATING
2° INCLINATION
57" ORIFICE HEIGHT
150°
200°
300°
500°
DISTANCE FROM JET NOZZLE — FT.
DISTANCE FROM CENTER LINE — FT.
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90
10 8 6 4 2 0 2 4 6 8 10

FIG. 2

FIG. 2

ESTIMATED TEMPERATURE CONTOURS

JT4A-3 ENGINE

TAKE-OFF RATING

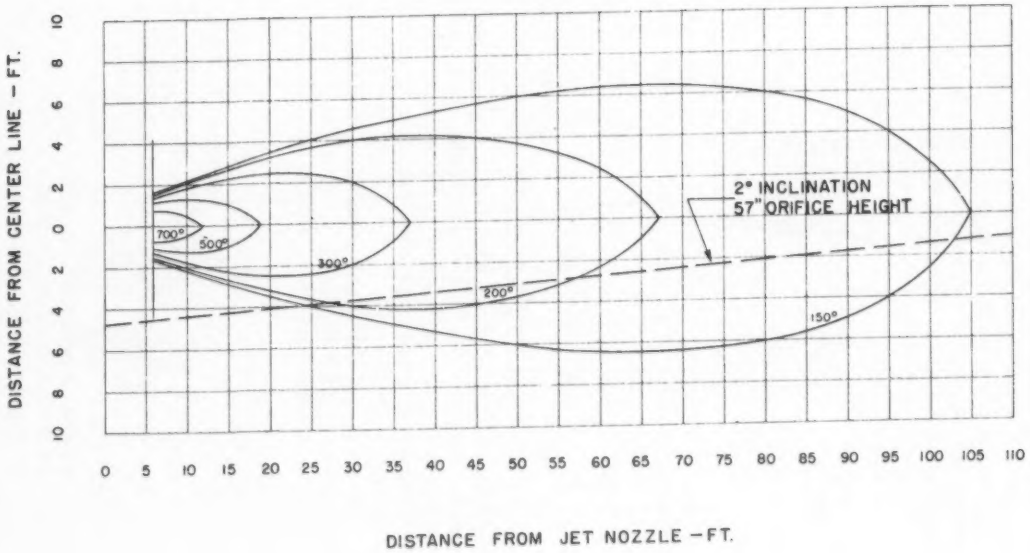

FIG. 3

ESTIMATED TEMPERATURE CONTOURS
CJ-805-21 AFT FAN ENGINE
TAKE-OFF RATING
4.6° INCLINATION
56.5" ORIFICE HEIGHT
150°
200°
400°
600°
800°
900°
DISTANCE FROM CENTER LINE - FT.
DISTANCE FROM JET NOZZLE - FT.
10 8 6 4 2 0 2 4 6 8 10
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38

FIG. 4

reflection characteristics when the pavement acts as a barrier.

The time of exposure of the pavement to the exhaust gases has an effect of producing high temperature peaks especially under full power conditions. The civil airport complex (runway-taxiway-apron) will not be subjected to the severe run-up operating conditions of the moving and nonmoving military aircraft for starting and pre-takeoff situations. A limited number of Boeing 707 aircraft operations recently were observed at Idlewild International Airport and the results are tabulated below and compared to published data for military aircraft:[4]

Aircraft	Engine Starting		Pre-Takeoff	
	Power	Time	Power	Time
Boeing 707	Idle to 20%	2.1 Min.	Idle to 20%	2 Min.
Military	Idle to 60%	10 Min.	Idle to 100%	2-1/2 Min.

For the above noted operating conditions at Idlewild International Airport, the time elements subsequent to the starting of the first engines are:

a) 2 minutes on the ramp
b) 1 minute being towed off ramp
c) 2 minutes on taxiway disengaging towing vehicle
d) 8 minutes for taxiing
e) 2 minutes on runway end prior to takeoff

Naturally, the taxiway time varies with the activity on the taxiways and the runway selections on any particular day. It can be expected that some of the time elements and the procedures involved will change from location to location; however, there is no indication of operating the engines at a rather high power setting for a considerable length of time while on the ground.

Studies conducted by the Corps of Engineers[1] indicate that high temperatures will melt the bituminous cement and blast erodes the pavement. The critical temperature for bituminous pavements are:

Asphaltic Concrete. . . . . Approximately 300° F
Tar Concrete . . . . . Approximately 250° F
Rubberized-Tar Concrete . . . . . Approximately 315° F

The only effect of heat and blast on portland cement concrete pavements is that some joint filler material will soften and be displaced. The indicated surface temperature of approximately 225° that will be induced in the pavements from the operations of the civil jet airliners are considerably below the reported critical range that produces erosion in the pavement. Reference is made to the critical pavement surface temperature since tests have clearly shown that temperature decrease rapidly with depth in the pavement, averaging 65° to 100° less at 1-inch depth than at the surface. Further, the civil operations on the ground and the aircraft type vary considerably from the military. Therefore, where civil operations are occurring, it can be expected that bituminous concrete pavements will give satisfactory performance.

In considering velocity effects, it follows that if heat causes no serious damage, then the velocity effect should be negligible. It is generally true that higher velocities obtain with high temperatures and these high temperatures are reached at full power where the maximum gas velocities are produced. In other words, if heat is causing any damage, it could be expected that

velocity of the gases would have increasing effect. Data available to our office indicate that the maximum velocity effect at ground level from engines mounted on the civil jets will occur about 35 feet behind the engine tailpipe. This point will normally occur on the pavement. The velocity at this point is approximately 300 miles per hour. At a distance of 100 feet from the airplane tail (165 feet from the nozzle), the velocity is of the order of 100 miles per hour. These results are typical of the JT3C-6 engines in the Boeing 707 aircraft at full power setting. Based on the above discussion relative to relationship of velocity and heat, the heat diagrams in Figures 2, 3, and 4, and the takeoff operation which employs a minimum time at the runway end, there does not appear to be any need for treatment or stabilization beyond runway ends to eliminate the effects of erosion. If the practice develops that a run-up operation is necessary prior to takeoff, then an area 100 feet in length for the width of the runway may require treatment.

Spillage

Studies have shown that spillage of gasoline for conventional aircraft and low volatility jet fuel for turbine-powered aircraft on asphalt pavements will leach the cement from the aggregate. Tar concrete is relatively unaffected by the action of jet fuel. One of the characteristics of the jet fuel is its slow rate of evaporation by comparison to gasoline. Occasional spillage will evaporate and cause no significant damage; repeated and continued spillage in any one area due to engine shutdown, refueling, and frequent fuel checks will produce softening and disintegration of the asphalt cement and will require special maintenance treatment.

In discussing heat and blast effects above, no reference was made to turboprop aircraft since their thrust is mainly derived from propellers and very little from the flow of hot gases through the jet orifice. However, it is necessary to consider this type of aircraft in discussing fuel spillage effects since they use the low volatility type of fuels.

The most critical areas where fuel spillage will cause distress to the bituminous pavements are refueling points, parking positions on aprons, and aircraft servicing areas. Recent observations at Washington National Airport which has a large number of turboprop aircraft operations give some indications of the source of spillage from these aircraft.

Viscount

Fueling operations indicated little or no spillage. For checking fuel volume, these aircraft are equipped with "dripsticks," one for each of the four fuel tanks. In this operation, fuel will flow through the tube and is allowed to flow onto the pavement. Approximately eight ounces of fuel could be spilled through each tube. Another source of spillage (1 pint) results when engines are turned off. Operation of this aircraft when turning from the runway or from one taxiway to another results in considerable spillage through the vent pipe of the fuel tank on the outside of the turn. The quantity spilled is a function of the fuel reserve. For this condition, the fuel is distributed over a rather large area.

Electra

This aircraft is equipped with a pan which collects any unburned fuel within the engine when the power is turned off. On takeoff, this fuel is blown from the pan by the air stream. No spillage occurred when refueling or checking the fuel level. For the fuel check, the "dripstick" is equipped with a drippings collector.

Fairchild F-27

No fuel spillage noted for refueling operation or fuel checking. There is slight spillage when the power is turned off. At Washington National Airport, portland cement concrete and asphaltic concrete pavements (with and without coal tar pitch emulsion seals) are in place at the gate positions. The portland cement concrete pavements show no signs of deterioration due to jet fuel spillage. The application of a coal tar emulsion seal to the bituminous pavements has proved beneficial, however the efficiency of the sealer is lowered when the surface is broken by locked-wheel turns, tire chains, and snow plows. During periods of heavy traffic concentration, aircraft are not always positioned on the concrete pad of the parking area and thus are parked on the bituminous surfaced areas. An area where fuel trucks are parked shows the effects of fuel leakage penetrating the pavement surface. On the hangar maintenance aprons, the asphaltic concrete surface is softening. This is undoubtedly due to heavy spillage of high detergent oils, brake fluid, and engine cleaning solvents. On the pavement areas outside of gate position and hangar areas, there is no indication of harmful effects of fuel spillage.

Conditions similar to those noted at Washington National Airport have been observed recently at other civil airports. It can be appreciated that maintenance techniques will play an important part in preserving asphalt pavement surfaces. The methods and materials used to blot up spilled fuel, cleaning procedures, surface washing with detergents, and needed surface resealing are all a function of operations at any specific airport.

The problem of fuel spillage on bituminous pavements will not become less when related to quantity of fuel used. Fuel volumes are at an all-time high for airline operations and the volumes are expected to increase. An indication of this is the optimum requirements of 1,200 gallons per minute for the jets with the approximate 400 gallons per minute for piston engines. The type of refueling equipment - trucks or hydrant systems - will affect the pavement performance.

CONCLUSIONS

Based on available data and limited observations of civil jet aircraft, the following conclusions are warranted at this time:

1. It can be expected that bituminous pavements will not be adversely affected by the heat and blast of turbine-powered civil aircraft.

2. In areas (refueling points, parking positions on aprons, and aircraft servicing) where fuel spillage is likely to occur, it will be necessary to provide a pavement surface resistant to the effects of jet fuel.

3. It does not appear necessary to stabilize the area contiguous to runway ends to prevent erosion.

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RUNWAY LIGHTING - NEW YORK INTERNATIONAL AIRPORT

John P. Veerling*

To meet the demands of increasing air traffic, The Port of New York Authority began in 1957 construction of the new instrument runway 4R-22L at New York International Airport (Idlewild). This runway which will be placed in operation this fall will be parallel to and 3000 feet east of the present instrument runway 4L-22R. Although existing 4L-22R is equipped with complete dual ILS and approach lights, this runway is lighted with the standard hi-intensity edge and threshold lights. The new runway 4R-22L will incorporate the best industry thoughts on visual aids from all sources to supplement and refine the concept developed by the Aviation Planning Division of the PNYA.

The following summary specifically describes the lighting features:

1. Elfaka type narrow gauge runway lighting as follows:
   a. 3000 feet on 100 foot spacing at each end of the runway. Inside gauge is 60 feet, outside 75 feet.
   b. Centerline lights spaced 100 feet apart starting at the termination of the narrow gauge lights and extending to end of runway.
   c. 1500 watt heaters for deicing each unit.
2. Hi-intensity runway lights longitudinally spaced 100 feet apart (usually 200 feet) and 150 feet laterally.
3. Four high-speed turnoffs (2 in each direction) located 3330 ft. and 5730 ft. from threshold at point of turn.
4. Centerline, surface mounted, low intensity, closely spaced lights to illuminate the centerline of the high-speed exit from the point of turn on the runway. The final selection of fixture and details of installation are expected to be made in the very near future. The problem has been one of resolving an installation that will have no surface protrusions to hinder the high-speed plowing operations that are necessary during periods of winter snow.

Note: Discussion open until December 1, 1959. To extend the closing date one month, a written request must be filed with the Executive Secretary, ASCE. Paper 2121 is part of the copyrighted Journal of the Air Transport Division, Proceedings of the American Society of Civil Engineers, Vol. 85, No. AT 3, July, 1959.

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5. Control systems - special features

   a. Narrow gauge may be operated on 100 or 200 foot spacing as desired.

   b. Because of distance of runway from control tower, positive indication will be provided to controllers that current is flowing to both narrow gauge lights and runway edge lights.

   c. Automatic stepdown from maximum brilliance to 25% (Step 5 to Step 4) after 15 min., on narrow gauge, thus requiring manual resetting. (Similar to approach light system.)

   d. Automatic turn-off of Elfaca fixture heater after 1 hour - requires resetting.

   e. Elapsed timers on Steps 5 & 4 of Elfaka lights.

The hi-intensity runway lighting installation which has been installed and flight tested at Dow Field and which is presently under construction at New York International Airport is significantly more expensive than the conventional standard. For that reason a more modest installation may be needed at airports of lower traffic intensity. Notwithstanding, the narrow gauge and centerline concept is very much worthy of consideration though its implementation may be of the pancake type fixture vice the flush hi-intensity fixture represented by the Elfaka unit.

Inasmuch as the effect of weather diversions is severely restrictive from the standpoint of fueling, passenger convenience and the aircraft utilization factor, the benefits should far exceed the cost of the new runway lighting installation.

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APPROACH AND RUNWAY LIGHTING AS VIEWED BY THE AIR LINE PILOT

Harold R. Miller*

First, I would like to read to you the Air Line Pilots Association Policy regarding Airport Lighting established by the ALPA Board of Directors in 1947, 1948 and 1950. Recommendations for airport lighting at all airports utilized by certificated carriers are:

1. Use of distinctive, high intensity runway lights that will not be confused with street lights, other miscellaneous lights, or reflections.

2. Runway lights that will not be rendered inaffective by ice and snow.

3. Runway lighting for daytime use under poor visibility conditions.

4. Runway lights that will be designed to prevent dangerous glare reflection.

5. Distinctive taxi strip lights, preferably blue in color.

6. Distinctive taxi strip designators designed for day and night usage (Board 1947).

Approach Lighting

The ALPA Center Line Approach Light System encompasses:

1. A system having a single row of Approach Lights installed on the extended center line of the runway.

2. Approach Lights be installed a minimum distance of 3,000 feet beginning from the ends of principal runways.

3. The System is to be visible through 180° (90° to either side of the approach path.)

4. That it be instantaneously identified and recognized as an approach light system under all conditions of reduced visibility. (Board 1950)

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Runway

ALPA recommends:

1. The installation of high intensity runway lights having a beam spread at least equal to that of the AGA type runway lights.

2. Lighted runway shall be plainly visible when circling through 360°, when approaching at 90° to the runway, and when on or approaching the extended center line of the runway.

3. To increase the efficiency of such lights under certain weather conditions and to prevent light blinding, the tower operator, without leaving his post of duty, should be able to regulate the intensity of the runway lights either by rheostat or other suitable means.

4. Only the runway in use should be lighted. This includes the green threshold lights.

5. All runway light controls should be located in the tower where the tower operator will have full control of the lights without leaving his post of duty. (Board 1948, 1950).

Today, some 9 to 12 years later, these recommendations have become a reality. Numerous Configuration "A" Approach Light systems are commissioned, or in the process of being installed at many of our airports. Most of these systems contain, or are programmed for the addition of Condenser Discharge Sequence Flashing equipment. Most airline pilots have had an opportunity to fly this system in marginal weather conditions and proclaim it to be the greatest contribution in the approach to all weather flying.

Captain Ernie Cutrell received the first ALPA Annual Safety Award at the ALPA Safety Forum in 1957 for his development of the ALPA Centerline System. We are ever grateful to Captain Cutrell, Captain John Gill of Eastern Air Lines, Mr. Jenks of FAA, Captain Dave Little of American Airlines, and many others who aided in the development of this system.

Some pilot complaints have been expressed concerning the blinding effect of the flasher units during low visibility approaches. Normally the flashers operate on a 3, 4, or 5 setting. During darkness, at near minimum operating conditions, experience shows the number 3 position to be the most desirable with the high intensity runway lights at the same setting or higher. During daylight, experience has shown the most desirable setting to be full bright for both approach and runway lights. Pilots that have gained considerable experience in the use of the Centerline System have become accustomed to requesting the desirable settings, consistent with weather conditions and the time of day. Through the media of the ALPA Tech Talk for pilots this experience is passed on to all members of ALPA for their guidance, when Center Line Systems are commissioned on their routes structures.

The runway visual range program is presently in operation at Idlewood, Newark, Los Angeles, and Washington. Some 25 other locations are programmed for installation in the near future. The approval of RVR as a low operating minimum requires the following:

1. High Intensity Runway Lights spaced 100 feet longitudinally for RVR of less than 2,600 feet and 200 feet longitudinally for RVR of 2,600 feet. (Presently, Newark is the only airport approved for 2,000 feet RVR).

2. Configuration "A" Approach Lights with Sequence Flashers

3. ILS or PAR

4. Transmissometer and Control Tower Indicator

5. TSO-N10A runway paint markings

6. Two Compass Locators

Pilot experience with RVR has been good. Pilot comments indicate that RVR is usually greater than reported, especially during night operation with no precipitation. During precipitation, experience has shown that RVR is generally the same as reported for night operation, and slightly less than reported during daylight hours.

The ALPA Lighting Committee has been active in evaluation of the Narrow Guage Runway Lighting System, the final phase in the approach to all weather flying. To date, this committee has evaluated the open grid, flush type, narrow guage runway center-line system, commonly known as ELFAKA, and found them to be excellent. This type lighting will enable the pilot to safely land his aircraft during times of extremely poor visibility.

On November 18, 19, 1958, the ALPA Committee were on hand at the IES Meeting at Dow Air Force Base, Maine to further evaluate the "ELFAKA" system. Under extremely poor weather conditions, they reported military aircraft from the B-52 to the F-104 made successful touchdowns in near zero, zero weather. They feel the one remaining need in the system is for a lighter centerline, commencing where the narrow guage stops, to provide guidance for the balance of the landing roll.

Recently, the ALPA Lighting Committee has received information on a new narrow guage lighting system called the Prismatic MC2 System. Since the ALPA Committee has not participated in the test installation at Atlantic City, the Association does not favor installation until thorough evaluation has been made for its members.

Information regarding the MC2 has been brought to the attention of our Washington Office, indicating due to the protrusion of some 1/2 to 3/4" above the runway surface of this unit, that objectionable vibration of the nose-wheel and instruments may be encountered, also there may be a snow removal problem during the winter months.

In conclusion, the Association favors a grid protected, flush, narrow-guage center line system identical to the ELFAKA installation programmed for Idlewild Airport.

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THE AIRPORT OPERATOR IN THE JET AGE

E. Thomas Burnard

There are over 7,000 airports in the United States today of which about 3,000 are publicly owned and available for public use. Most of these airports serve general aviation exclusively, however, since air carriers utilize only about 550 of the Nation's airports. And of these airports served by air carriers, the FAA classifies only 163 as "air traffic hubs." To be classified as a "hub" a community must produce more than 5/100 of one percent of the Nation's enplaned airline passengers. Last year this meant at least 22,000 passengers.

These 163 "hubs" handle over 95 percent of the Nation's enplaned scheduled air carrier passengers and are further subdivided as follows:

22 large hubs - that is, the cities enplaning over 1 percent of the Nation's total or at least 440,000 passengers last year.

42 medium hubs which enplaned between 110,000 and 440,000 passengers last year or, percentage-wise, from 1/4 to 1 percent of the Nation's total.

97 small hubs, or those communities enplaning less than 1/4 of 1 percent but more than 5/100ths, which includes those cities where from 22,000 to 110,000 passengers were enplaned last year.

The ownership and operation of these airports involves the development, management, operation and maintenance of a very large piece of improved real estate for use by tenants and users with very peculiar and special requirements so that the public - local, national and international - will be adequately served with air transportation.

The taxpayers are hopeful that this can be done without cost to them — and the users hope that it will be done without cost to them!

For these, among other reasons, the airport operator in the jet age is faced with many complex problems. For convenience I will discuss them under four main categories of functions and responsibilities of the airport operator.

Briefly these functions may be described as follows:

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a. Property Development
b. Property Management
c. Aeronautical Specialist
d. Public Service

The first two of these functions are not too dissimilar from the well-recognized property development and property management functions in the business world. The aeronautical specialist function is one which differentiates an airport operator from a shopping center or an apartment development operator; and the public service function of the airport operator is the one that complicates his life greatly.

a. Property Development

The property development function is one in which the airport operator relies heavily on the master-planner, the architects and engineers, the financiers and the big construction outfits. Current estimates put the capital investment in airport facilities in this country somewhere between $3 and $4 billion, and the most recent national survey by the Federal Aviation Agency estimated that over a billion dollars of airport development is taking place and needed within the next four years. This development of thousands and thousands of acres of land to accommodate today's airplanes as well as tomorrow's, involves profound decisions - both with respect to the physical development of the property as well as the raising of capital. To assure that the capital invested will not be jeopardized by technological obsolescence, and to assure that it has a chance of some degree of self-support, the master-planning must be accurate, the engineering and architectural work must be efficient, the financing must be adequate, and the construction must be competent.

1) Perhaps the greatest single problem today in this property development function is that of financing. The general obligation bond which commits the full faith and credit of the community to provide the funds for airport development is gradually becoming less appealing to the taxpayers and more emphasis must be put on other forms of capital.

The huge capital improvement programs needed at most airports are beyond the capability of the local communities to provide alone. Consequently, the Federal Aid to Airport Program must be continued to get the airports "over the hump" in these major capital improvement programs. Although some people erroneously believe that the Federal Aid Program contributes to the maintenance and operating costs of airports, I am sure that this sophisticated audience realizes that Federal funds are only available for capital improvement expenditures; and that, although the Federal Government may participate up to 50 percent in some projects (which has brought about the so-called 50-50 way to describing the program), the fact of the matter is that as the size of the airport project increases in total amount, historically the participation by the Federal Government has been smaller in percentage. In absolute dollars, however, it is just as essential to get 10 to 20 percent Federal aid in a large project as it is to get 50 percent Federal aid in a small project.

There is currently pending before the Congress, awaiting action by a conference between the House and the Senate, an airport bill which was passed by the Senate in the total amount of $465 million for a four-year

period, and by the House in the total amount of $297 million for a four-year period. This money difference, together with the eligibility of terminal and other buildings, comprise the two principal issues in these versions. The Administration, however, has proposed a still different version which would total only $200 million for a four-year period. Although no formal date had been set for the Conference Committee to meet, it is expected that they will do so in the very near future, and we sincerely hope that the President will see fit to sign into law the fruits of their labor.

In addition to general obligation bonds and Federal aid, other forms of financing include revenue bonds, about which you heard something this morning. Tenant financing and bank loans are other forms of financing which are used in various forms for hangars and other aspects of airport development.

2) The other main problem in the property development function is that of trying to anticipate the long-range land use, economic and technological developments. It is in this area that airport operators need the best advice possible in preparing master plans for future expansion of present facilities and the location and construction of new ones. Civil Engineers can, and do, render a real service in this field.

To help both of us, however we need much more research in airport problems.

We need to know more about the placement of one or more airports to serve a community or region; about the relationship between airport configuration and airport capacity; about airport layout and efficiency of operation; about terminal area design and ground servicing; and about the effects on airports of new air vehicles and refinements of old ones.

The FAA Office of Plans and Requirements as well as in their Bureau of Research and Development are beginning to take hold of some of these problems, but the ASCE, the Universities, and others can all help.

b. Property Management

The property management function of airport operators has many things in common with the management of an office building, an apartment building, a shopping center, and the like. In addition to maintaining and operating the premises in good condition, the property management functions include the vital matter of holding expenses down and improving revenues. It is basically a "landlord" function.

Although airport operators are constantly seeking new and better ways to maintain and operate their facilities, perhaps the most critical and time-consuming problems come in the revenue and expense area of their property management duties.

As mentioned earlier, most airports served by the airlines and used by general aviation are publicly owned and operated. The airport operators have both a moral and frequently a legal requirement to operate their fields on a self-supporting basis; and self-supporting doesn't just mean obtaining enough revenues to meet current operating expenses. It means acquiring enough revenues to set up a reserve for depreciation, to pay the interest and amortize the debts; and over and above that, as any good businessman knows, it is necessary to acquire enough surplus to provide for the huge capital investments that are necessary to expand existing facilities and provide new facilities so that the terrific growth rate which aviation enjoys can be satisfied at the airport both today and in the future.

It is for this reason that the improvement of revenues constitutes the greatest problem confronting airport operators in their role as property managers.

Revenues are produced from landing or use fees, hangar rentals and fixed base services, terminal area services and from industrial and other non-aviation activities at the airport. Many airports are still laboring under agreements with users which date back ten, twenty and even thirty or more years at very low rates and with little or no chance of re-negotiating those contracts to provide a more favorable rate of return. Although sometimes airline spokesmen might imply that landing fees are exhorbitant, the fact of the matter is that last year landing fees cost the airlines less that ONE CENT out of each dollar of gross operating revenue.

The terminal building has revenue producing services both inside and adjacent to the building which provide a high percent of airport revenues. They involve negotiative contracts with, and keeping happy, dozens of tenants who render services to the traveling public. It also involves negotiations with the Post Office, and other Government tenants.

Thus, the airport operator finds himself spending a great deal of time as a property manager dealing with the airlines, the concessionaires, the Federal Government tenants, the industrial tenants and the other airport users, all of whom are extremely important to the airport and all of whom should contribute their fair share to the provision and operation of this facility.

c. Aeronautical Specialist

The third function and responsibility of the airport operator is that of being an aeronautical specialist. No other landlord or property developer has the kind of peculiar requirements of tenants - that airport operators do. There is no other form of transportation that has experienced the radical changes that we have seen in aviation in just a little over a decade.

For instance, the weight of transport aircraft has gone from vehicles in the 1,000s of pounds fo currently flying airplanes of 150 tons. Speakers on this program as well as others freely predict air vehicles in civil transport service weighing 250 tons within the next five to ten years, and aircraft of that size are already operating in the military service.

We have also seen airplanes go from those carrying from 10 to 20 passengers to present planes which will carry in the neighborhood of 125 to 180 and we have every reason to believe that aircraft carrying from 200 to 300 will not be out of the question in the next decade.

Speeds of aircraft have gone from about 100 miles an hour to just under the speed of sound for some of the newest transport aircraft. There are currently flying military aircraft, however, which operate in the Mach 2 and Mach 3 range of up to 2,000 miles per hour; and representatives from the manufacturers very matter of factly tell us that the transport of 1970 for long-range operations may well be the Mach 3 transport which flies from San Francisco to New York in about an hour and a half.

We have seen runway lengths go from approximately 2,000 feet to 2 miles; and we like to think that this continuation of runway lengths is not going on forever. We have had some of our greatest encouragement in this regard from recent remarks by the Federal Aviation Agency officials. At the Airport Operators' Council meeting in Portland two weeks ago, General Marcus

Cooper, Assistant Administrator for Plans and Requirements, told our group that it is time for an abrupt halt in the ever-increasing requirements for concrete that are brought about by each new group of airplanes. Administrator Quesada said essentially the same thing in Washington last week when he said that "cities cannot be expected to go on extending the size, length and thickness of airport runways to accommodate bigger, faster and heavier airplanes." And perhaps even more significant is the statement by the Senate Interstate and Foreign Commerce Committee of the 86th Congress, in their report on the Federal Airport Act, that "the jet age revolution in aircraft design and characteristics has brought with it the now vital problem of assuring that airport facilities and aircraft requirements are kept realistically in balance . . . it is time that aircraft be designed to fit the airport system and not vice versa."

One of the aeronautical phenomenon that complicates the airport operators life greatly is that all of these transport aircraft, plus personal and business planes, old and new, are still flying, and all of them seem to want to use the same airports at the same time.

In the next decade we expect to see great strides in VTOL and STOL techniques; in "aerial buses," "aerial trains," and eventually space ports. A complicating feature in these developments, however, is the fact that the military and high government policy determine to a large extent the technical developments of the aircraft and the fiscal policies of the air transport system. Thus, the stroke of a pen in Washington can shatter the best laid plans of airport men.

A further complicating fact is that civil and military users have different requirements at the same airports. There is also the not-so-small matter of coordinating United States requirements with those of the International Civil Aviation Organization which now includes over 75 nations of the free world.

Underlying most of the airport operators' problems in trying to keep abreast of aeronautical developments, however, is the historic lack of "systems approach" to the development of the aircraft, the airways and the airports. We in the AOC have advocated for some time now that there must be better coordination and better integration of planning between the aircraft manufacturer, the aircraft operator and the ground facility providers to eliminate much of the inefficiency in both the government and the industry. It is a matter which ideally should be done voluntarily but, lacking that, government regulation or even legislation may be required. We believe we see some signs of better integration under the FAA, but it is a little too early to judge exactly how effective this will be.

Thus, perhaps the most difficult problem confronting the airport operators in this technical field is that of staying abreast of the technical developments so that the huge capital investment in airports can be protected; and so that changes in requirements can be anticipated far enough in advance to make possible appropriate technical as well as financial planning.

d. Public Service

The fourth and last category of the airport operator's function and responsibility is that of rendering a public service. Like all forms of common carrier transportation, air transportation's reason for being is that of rendering a service to the public. An airport, like an airline, exists to contribute its part of the air transport system which makes possible a strong national

economy and a strong national defense. An outstanding service to the public is now being rendered by air transport and it is capable of doing an even better job.

But matters of public service automatically bring with them controls and expertese from many sources; As airport operators we are therefore seeking the most efficient management organizations that we can. This management should be capable of producing the best kind of service to the public at the lowest cost to the users and preferably without cost to the taxpayers.

Airports are presently operated by several different forms of management entities. The most direct and the simplest of these is the corporate type which is self-contained both as to ownership and operation. Lockheed Air Terminal at Burbank, California, for instance, is an example of private enterprise ownership and operation of airports. Closely allied with this form of management organization are the operating corporations such as Fort Worth Air Terminal, Inc. and the Airlines National Terminal Service Co. at Willow Run Airport, Detroit. In each of these cases the airport is owned by a public body but operated by a private corporation.

The simplest of the public agency type of airport organization, and one in which decisions can be arrived at without referral to political groups, is that of the airport board, airport authority or post authority which is set up either to operate an airport exclusively or to operate airport facilities together with other transportation facilities. Examples of these would be the Louisville and Jefferson County Air Board in Kentucky, the Port of Seattle or the Port of New York Authority, which can borrow money on their own and operate generally along the lines of a private corporation.

The next form of management and operation of airports which involves more direct political control is that of a Department of Aviation within a municipal or county structure. Although not autonomous, the Department of Aviation in those communities having this form of management, operates relatively independent of the other municipal or county functions although there is the usual departmental scramble for funds and personnel and the integration of the long-range capital improvement programs.

The earliest, and still the most widespread management form among medium and smaller size communities, is that of airport operation as a part of the department of public works, public parks, streets or the like. In those cases, budgets and decisions relating to the operation of the airport must be blended with those of other functions performed in that department, and these in turn must be integrated with the overall municipal or county functions.

Regardless of the form of management organization, however, those public officials involved in the airport operation are probably unique in that there are perhaps no other public officials who need to know so much about so many non-governmental functions as these airport officials.

Airports have far outgrown the purely local considerations of yesteryear, and we are now well into the jet age which makes us an integral part of both the national and the international air transport system. To fulfill our obligations and responsibilities in this important role we must be technically right and financially strong.

Civil engineers can do much to help us be both.

PROCEEDINGS PAPERS

The technical papers published in the past year are identified by number below. Technical-division sponsorship is indicated by an abbreviation at the end of each Paper Number, the symbols referring to: Air Transport (AT), City Planning (CP), Construction (CO), Engineering Mechanics (EM), Highway (HW), Hydraulics (HY), Irrigation and Drainage (IR), Pipeline (PL), Power (PO), Sanitary Engineering (SA), Soil Mechanics and Foundations (SM), Structural (ST), Surveying and Mapping (SU), and Waterways and Harbors (WW), divisions. Papers sponsored by the Department of Conditions of Practice are identified by the symbols (PP). For titles and order coupons, refer to the appropriate issue of "Civil Engineering." Beginning with Volume 82 (January 1956) papers were published in Journals of the various Technical Divisions. To locate papers in the Journals, the symbols after the paper number are followed by a numeral designating the issue of a particular Journal in which the paper appeared. For example, Paper 1859 is identified as 1859 (HY7) which indicates that the paper is contained in the seventh issue of the Journal of the Hydraulics Division during 1958.

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JULY: 1692(EM3), 1693(EM3), 1694(ST4), 1695(ST4), 1696(ST4), 1697(SU2), 1698(SU2), 1699(SU2), 1700(SU2), 1701(SA4), 1702(SA4), 1703(SA4), 1704(SA4), 1705(SA4), 1706(EM3), 1707(ST4), 1708(ST4), 1709(ST4), 1710 (ST4), 1711(ST4), 1712(ST4), 1713(SU2), 1714(SA4), 1715(SA4), 1716(SU2), 1717(SA4), 1718(EM3), 1719 (EM3), 1720(SU2), 1721(ST4)[c], 1722(ST4), 1723(ST4), 1724(EM3)[c].

AUGUST: 1725(HY4), 1726(HY4), 1727(SM3), 1728(SM3), 1729(SM3), 1730(SM3), 1731(SM3), 1732(SM3), 1733 (PO4), 1734(PO4), 1735(PO4), 1736(PO4), 1737(PO4), 1738(PO4), 1739(PO4), 1740(PO4), 1741(PO4), 1742 (PO4), 1743(PO4), 1744(PO4), 1745(PO4), 1746(PO4), 1747(PO4), 1748(PO4), 1749(PO4).

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FEBRUARY: 1933(HY2), 1934(HY2), 1935(HY2), 1936(SM1), 1937(SM1), 1938(ST2), 1939(ST2), 1940(ST2), 1941(ST2), 1942(ST2), 1943(ST2), 1944(ST2), 1945(HY2), 1946(PO1), 1947(PO1), 1948(PO1), 1949(PO1), 1950(HY2)[c], 1951(SM1)[c], 1952(ST2)[c], 1953(PO1)[c], 1954(CO1), 1955(CO1), 1956(CO), 1957(CO1), 1958(CO1), 1959(CO1).

MARCH: 1960(HY3), 1961(HY3), 1962(HY3), 1963(IR1), 1964(IR1), 1965(IR1), 1966(IR1), 1967(SA2), 1968(SA2), 1969(ST3), 1970(ST3), 1971(ST3), 1972(ST3), 1973(ST3), 1971(ST3), 1975(ST3), 1976(WW1), 1977(WW1), 1978(WW1), 1979(WW1), 1980(WW1), 1981(WW1), 1982(WW1), 1983(WW1), 1984(SA2), 1985(SA2)[c], 1986 (IR1)[c], 1987(WW1)[c], 1988(ST3)[c], 1989(HY3)[c].

APRIL: 1990(EM2), 1991(EM2), 1992(EM2), 1993(HW2), 1994(HY4), 1995(HY4), 1996(HY4), 1997(HY4), 1998 (SM2), 1999(SM2), 2000(SM2), 2001(SM2), 2002(ST4), 2003(ST4), 2004(ST4), 2005(ST4), 2006(PO2), 2007 (HW2)[c], 2008(EM2)[c], 2009(ST4)[c], 2010(SM2)[c], 2011(SM2)[c], 2012(HY4)[c], 2013(PO2)[c].

MAY: 2014(AT2), 2015(AT2), 2016(AT2), 2017(HY5), 2018(HY5), 2019(HY5), 2020(HY5), 2021(HY5), 2022(HY5), 2023(PL2), 2024(PL2), 2025(PL2), 2026(PP1), 2027(PP1), 2028(PP1), 2029(PP1), 2030(SA3), 2031(SA3), 2032(SA3), 2033(SA3), 2034(ST5), 2035(ST5), 2036(ST5), 2037(ST5), 2038(PL2), 2039(PL2), 2040(AT2)[c]. 2041(PL2)[c], 2042(PP1)[c], 2043(ST5)[c], 2044(SA3)[c], 2045(HY5)[c], 2046(PP1), 2047(PP1).

JUNE: 2048(CP1), 2049(CP1), 2050(CP1), 2051(CP1), 2052(CP1), 2053(CP1), 2054(CP1), 2055(CP1), 2056 (HY6), 2057(HY6), 2058(HY6), 2059(IR2), 2060(IR2), 2061(PO3), 2062(SM3), 2063(SM3), 2064(SM3), 2065 (ST6), 2066(WW2), 2067(WW2), 2068(WW2), 2069(WW2), 2070(WW2), 2071(WW2), 2072(CP1)[c], 2073(IR2)[c], 2074(PO3)[c], 2075(ST6)[c], 2076(HY6)[c], 2077(SM3)[c], 2078(WW2)[c].

JULY: 2079(HY7), 2080(HY7), 2081(HY7), 2082(HY7), 2083(HY7), 2084(HY7), 2085(HY7), 2086(SA4), 2087 (SA4), 2088(SA4), 2089(SA4), 2090(SA4), 2091(EM3), 2092(EM3), 2093(EM3), 2094(EM3), 2095(EM3), 2096 (EM3), 2097(HY7)[c], 2098(SA4)[c], 2099(EM3)[c], 2100(AT3), 2101(AT3), 2102(AT3), 2103(AT3), 2104(AT3), 2105(AT3), 2106(AT3), 2107(AT3), 2108(AT3), 2109(AT3), 2110(AT3), 2111(AT3), 2112(AT3), 2113(AT3), 2114(AT3), 2115(AT3), 2116(AT3), 2117(AT3), 2118(AT3), 2119(AT3), 2120(AT3), 2121(AT3), 2122(AT3), 2123(AT3), 2124(AT3), 2125(AT3).

c. Discussion of several papers, grouped by divisions.

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